COMPARATIVE EVALUATION OF THE MASKING ABILITY OF LITHIUM DISILICATE CERAMIC WITH DIFFERENT CORE THICKNESS ON THE SHADE MATCH OF INDIRECT RESTORATIONS OVER METALLIC SUBSTRATE - AN *IN VITRO* STUDY

Dissertation Submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH I

PROSTHODONTICS AND CROWN & BRIDGE

MAY 2018

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY
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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"COMPARATIVE EVALUATION OF THE MASKING ABILITY OF LITHIUM DISILICATE CERAMIC WITH DIFFERENT CORE THICKNESS ON THE SHADE MATCH OF INDIRECT RESTORATIONS OVER METALLIC SUBSTRATE - AN *IN VITRO* STUDY"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. S. JAYA KRISHNA KUMAR, M.D.S.,** Professor, Department of Prosthodontics and Crown & Bridge, Ragas Dental College and Hospital, Chennai.

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This dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the Degree of **MASTER OF DENTAL SURGERY – PROSTHODONTICS AND CROWN & BRIDGE, BRANCH I.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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Introduction

INTRODUCTION

Porcelain - fused to metal restorations have been regarded the gold standard in fixed prosthodontics with 94% success rate over 10 years with good mechanical properties, reasonable aesthetics and an acceptable biological quality required for its service .[13,27,35,39,55] However, Porcelain - fused to metal prosthesis have some limitations , which include increased light reflectivity from the opaque porcelain used to mask the metal coping and occasional greying of the gingival tissues resulting in an unattractive appearance.[42,50,56] This has led to the introduction of metal free restorations as an alternative to metal-ceramic restorations in daily clinical practice especially for anterior aesthetic restorations.[4,9,54,67]

Newer metal free crowns are increasingly been used in dental practice and these crowns are made from different ceramic materials such as leucite-reinforced glass, lithium disilicate, glass-infiltrated alumina and zirconia.[37,45,62] The high strength core ceramics such as alumina or zirconia-based ceramics have high opacity and hence require translucent veneering porcelain to achieve adequate shade matching.[6] Among the semi-translucent glass-ceramic systems, lithium disilicate has gained popularity for both anterior and posterior crowns because of its superior aesthetics , adequate strength, wear resistance and chemical durability. [11,17,40]

Lithium disilicate is a ceramic material that contains 70% by volume, needle like crystals in a glassy matrix. The controlled size, shape and density of this structure results in restoration that demonstrates greater strength and durability. [1,2,59] This material has a low refractive index, a characteristic that allows the material to exhibit phenomenal optical properties and optimal esthetics.[6,35] Lithium disilicate glass ceramic can be processed using either the lost-wax hot press technique or CAD/CAM version [18]. The popularity of Heat pressed ceramics has risen markedly due to its similarity to conventional lost-wax technique and also the equipments required to heat press ceramics is relatively inexpensive. [21,25,33]

IPS emax Press Lithium disilicate ceramic presents relatively high flexural strength (350-400MPa) and increased fracture toughness due to its smaller and more homogeneous crystals .[10,32] IPS emax Press has been used successfully for monolithic fixed partial dentures even in the posterior area for as long as 8 years .[73]

The translucent core of all-ceramic crowns when indicated for masking heavily discoloured teeth, titanium abutments, pre existing post and core metallic foundation ,will have a detrimental effect on the optical behaviour of the final restoration.[10,12,23,46,47,59] The masking effect of the ceramic material is primarily dependent on its translucent property. The translucency is indirectly proportional to the thickness of the core ceramic utilised.[5] Increase in thickness of the restoration can solve the problem of masking heavily discoloured abutment.[15] However, extensive tooth preparation or over contouring the restoration may violate the biological principle .[12]

Several modalities have been employed in attaining an aesthetic restoration. One such method makes use of translucent core ceramic with an opaque cement to mask the substrate, as translucent ceramics have the greatest potential to be affected adversely by the discoloured substrate, but this often produces an undesirable result, as the final shade of the crown is subject to change after cementation. A far more predictable approach is to use a crown with a more opaque core that is less affected by the abutment colour. The layered ceramic systems with more opaque cores are well suited for the treatment of discoloured teeth .[24]

Shade selection has a positive impact on the patient’s perception of aesthetics and ultimately, the acceptance of their restorations. [4,7,14] Shade matching in clinical practice is obtained by visual assessment and instrument colour analysis .Researchers have shown that visual shade selection is often unreliable and imprecise and have increasingly recommended the use of instrument colour analysis by colorimeters and spectrophotometers.[16,28,67] Compared with observations by the human eye or conventional techniques, it was found that spectrophotometers offered a 33% increase in accuracy and a more objective match in 93.3% of cases. [51]

Quantitative analysis of colour coordinates using CIELAB colour system with spectrophotometer have been acclaimed universally in the dental community and is regarded a benchmark for research purposes and helps to scrutinize the results with those obtained from conventional shade tabs .[20,22,70] The capacity of the human eye to notice differences in colour varies among individuals, different

ΔE values are used to distinguish differences in colour: ΔE values < 1 is considered undetectable by the human eye. Studies have used different ΔE values as clinically acceptable: 3.3 as the perceptibility limit, 5.5 as the acceptability tolerance. [12,13,31]

Previous studies have evaluated the masking ability of feldspathic and leucite ceramics, studies evaluating the optical properties of lithium disilicate pressable ceramic and Ni-Cr alloys as anterior indirect restorative materials are very few.

The application of lithium disilicate ceramic material with different translucency blanks for masking different substrate colours are in its early stages and results pertaining to its masking ability are few.

Since the optical properties of all-ceramic restorative material is of paramount consideration with regards to patient's expectation, the translucency parameter of these materials needs to be further evaluated .Moreover comparative *in vitro* studies evaluating the masking ability of lithium disilicate ceramic material of different core thickness over metallic substrates are sparse.

In view of the above, the present *in vitro* study was conducted to comparatively evaluate the masking ability of different core thickness of Lithium disilicate ceramic on the shade match of indirect restorations over metallic substrate. The null hypothesis of the present study is that different core thickness of lithium disilicate ceramic material will not have any significant difference in masking ability over metallic substrates.

OBJECTIVES:

1) To evaluate quantitatively, the L*a*b* values of lithium disilicate ceramic discs of 1mm thickness against white background.

2) To evaluate quantitatively, the L*a*b* values of lithium disilicate ceramic discs of 1.3mm thickness against white background.

3) To evaluate quantitatively, the L*a* b* values of lithium disilicate ceramic discs of 1.6mm thickness against white background.

4) To evaluate quantitatively, the L*a*b* values of lithium disilicate ceramic discs of 1 mm thickness against Ni-Cr metal discs before cementation.

5) To evaluate quantitatively the L*a*b* values of lithium disilicate ceramic discs of 1.3 mm thickness against Ni-Cr metal discs before cementation.

6) To evaluate quantitatively the L*a*b* values of lithium disilicate ceramic discs of 1.6 mm thickness against Ni-Cr metal discs before cementation.

7) To evaluate quantitatively the L*a*b* values of lithium disilicate ceramic discs of 1 mm thickness after cementation with Ni-Cr specimens.

8) To evaluate quantitatively the L*a*b* values of lithium disilicate ceramic discs of 1.3 mm thickness after cementation with Ni-Cr metal discs.

9) To evaluate quantitatively the L*a*b* values of lithium disilicate ceramic discs of 1.6mm thickness after cementation with Ni-Cr metal discs.

10) To evaluate the colour difference (ΔE) of 1mm, 1.3mm and 1.6mm Lithium disilicate ceramic discs against white background and Ni-Cr metal discs before cementation.

11) To evaluate the colour difference (ΔE) of 1mm, 1.3mm and 1.6mm Lithium disilicate ceramic discs against white background and Ni-Cr metal discs after cementation.

12) To comparatively evaluate the mean colour difference value (ΔE) between 1mm, 1.3mm and 1.6mm lithium disilicate ceramic discs before cementation respectively.

13) To comparatively evaluate the mean colour difference value (ΔE) between 1mm, 1.3mm and 1.6mm lithium disilicate ceramic discs after cementation respectively.

14) To comparatively evaluate the mean colour difference (ΔE) observed within 1mm, 1.3mm and 1.6mm lithium disilicate ceramic discs respectively before and after cementation.

Review of Literature

REVIEW OF LITERATURE

Rosenblum *et al* (1997)[55] explains about the evolution of ceramic restorations from porcelain fused to metal restorations and their drawbacks which prompted the development of new all-ceramic systems. The author summarises on the different types of all ceramic materials currently available, from the conventional powder slurry ceramics, castable ceramic, machinable pressable and infiltrated ceramics. The author compares the physical properties of the different systems and suggests the use of stronger materials in stress bearing areas and softer materials in situations in which tooth abrasion may be critical (lingual surfaces of upper anterior teeth).

Vichi *et al* (2000)[69] evaluated the influence of the colour of two commercially available non-metallic opaque posts (carbon fiber and zirconia) and an experimental aesthetic post with white yellow ,brown shade luting cements of thickness 0.1 and 0.2mm on the aesthetics of IPS Empress ceramic restorations. The study concluded that 2mm thick IPS Empress restoration was not affected by discoloured substrates but when the thickness reduced to 1.5 mm there was a need to evaluate the substrate.

Carossa *et al* (2001)[9] studied about the effect of polished and matte-finished gold alloy, all-ceramic, and ceramized metal alloy posts and cores on light transmission through IPS-Empress 2 surface-coloured, IPS Empress 2 stratified, and In-Ceram all-ceramic crowns. The study revealed surface coloured glass ceramic IPS-Empress had the highest luminance because of the greater translucency of the material, concerned with the posts and cores at the standard crown thickness used, the matte-finished gold alloy had the lowest luminance and ceramized metal and polished gold alloy posts and cores had intermediate values of luminance that were very similar to each other**.**

Heffernan ***et al*** **(2002)**[35]evaluated the Relative translucency of six all-ceramic core materials at clinically appropriate thicknesses **.**These cores can be veneered with porcelain in clinical practice to improve the esthetics. The thickness of a core material affects its strength and optical properties .On the basis of translucency, In-Ceram Spinell may be recommended for matching adjacent, highly translucent natural teeth .For moderately translucent teeth, Empress, Procera and Empress 2 were feasible restorative materials. In-Ceram Alumina may be used for moderately opaque teeth; for opaque teeth, there may be no difference in the translucency of In-Ceram Zirconia and a metal-ceramic restoration

Nakamura ***et al*** **(2002**) [48] explains the effect of the abutment substrate on the final aesthetic appearance of the all-ceramic crown as light passes through it. The cast post and core is constructed after the root-canal treatment, making it necessary to consider not only the colour of the crown but also the colour of the abutment tooth involved. The author studied, the effect of different backgrounds, gold alloy background simulating a conventional cast post, and two porcelain background simulating a porcelain veneered cast post on Empress crowns for restorations. When making a cast post using gold-alloy, the dentin ceramic must be more than 1.6 mm thick; in cases where this thickness cannot be attained, it is effective to make a post using tooth-coloured material, such as a porcelain veneered cast post.

Dozic *et al* (2003)[29] evaluated quantitatively, the effect of different thickness ratios of opaque porcelain (OP) and translucent porcelain (TP) layers on the overall shade of all-ceramic specimens. The author explained that even small changes in OP/TP thickness ratio can perceivably influence the final shade of the layered specimens ($\Delta E > 1$). Redness a* and yellowness b* increased with the thickness of OP for all shades. Redness a* ($p < 0.01$) for all shades) correlated more strongly with thickness than yellowness b* with ($p < 0.01$) for A1 and A3; ($p < 0.05$)for A2. The lightness (L*) was shade dependent. A thickness of 0.70 mm of the Core material tested is sufficient to mask the influence of the background colour on the final shade of the layered specimens.

Burkinshaw (2004)[7] the author explains about the perception of the colour of an object, as a result of interactions between a light source, an object and an observer. The author also explains about the fundamental aspects of light sources, the ways in which light interacts with an object either by reflection , absorption and transmittance. Characteristics of the observer and principles of human colour vision are discussed .The study also explains about CIE 1931 colour system and the essentials of colorimeter and spectrophotometer and their mechanism of function.

Kelly *et al* (2004) [39]explains the three main divisions to the spectrum of dental ceramics: (1) predominantly glassy materials, (2) particle-filled glasses, and (3) polycrystalline ceramics .All-ceramic systems can provide a better esthetic result than metal-ceramics because a wide range of translucency-opacity can be achieved with commercially available ceramic systems. Other advantages of all-ceramic restorations over metal ceramics include better emergence profile, better soft tissue health leaving the margin supragingival or at the gingival margin enabling preservation of biological width.

Raptis *et al* (2006)[54] summarizes on the history of clinical success of porcelain fused metal restorations with combined good aesthetic results and inherent strength. The author also evaluates on its limitations and alternative methods of fabrication of restoration thereby improving shade replication of restoration. The options include metal-ceramic crowns with castings 2 mm short of the shoulder preparation and 360-degree porcelain margins permitted light transmission through gingival portion of tooth. IPS Empress and In-Ceram Spinell all-ceramic restorations demonstrated equally good light transmission properties. In-Ceram Spinell presented better reflection and refraction characteristics, as well as colour matching properties, compared to restoration with a 2-mm short coping and 360-degree porcelain margin.

Sadowsky *et al* (2006)[56]gives a systematic review on the different restorative materials including the silver amalgam restoration ,direct and indirect composite resins ,porcelain laminates ,all-ceramic crowns and all- ceramic fixed partial dentures. The author explains on the advantages of all-ceramic restorations over metal-ceramic restorations and the importance the ceramic coping design on the long term success of restoration .The author also summarises the importance of toughened ceramics and its indication in stress bearing area. With innovations in biocompatibility, strength, marginal adaptation and optical qualities of dental materials, the prognosis of esthetic restorations appears to depend predominantly on choice of material, precise technique and patient selection.

Shimada *et al* (2006)[60] evaluated the influence of composite build-up material , a gold alloy and a silver palladium alloy as abutment materials on the colour of IPS Empress 2 ceramic coping with different thicknesses 0.8, 1.0 ,1.2 ,1.4 ,1.6, 1.8 ,and 2.0 mm. For the IPS Empress 2 ceramic coping, minimum thickness of 0.8 mm recommended by the manufacturer is appropriate .Ceramic copings of Empress 2 of 1.6 mm thickness or more , prevented the abutment materials to exert any clinically unacceptable colour influence

Chu *et al* (2007)[15] studied the contrast ratios and masking abilities of Procera , Empress 2 and Vitadur Alpha all ceramic veneers over white and black backgrounds by measuring their luminance and colour difference. Vitadur Alpha had significantly lower contrast ratio with reduced masking ability compared to Procera or Empress 2. It was found that masking efficiency of Empress 2 was lower than Procera cores due to the reduced crystal volumes. The clinical application of these two ceramics as a veneer material may still be limited when applied over intense tooth discolouration because neither can fully mask the colour of a black background.

Conrad *et al* (2007)[17] reviews the current literature on all-ceramic materials and systems, with regards to survival, marginal and internal fit, material properties, cementation and bonding, colour and esthetics and provides clinical recommendations for their use. The review demonstrates the multiple all-ceramic materials and systems currently available for clinical use and suggest that there is not a single universal material or system for all clinical situations. The successful application is dependent upon the clinician's ability to match the materials, manufacturing techniques and cementation or bonding procedures, with the individual clinical situation.

Douglas *et al* (2007)[28] studied about the acceptability and perceptibility tolerances for shade mismatch using spectrophotometric analysis. Tolerances for acceptability were significantly higher than tolerances for perceptibility of shade mismatch between 2 artificial acrylic resin teeth. The author revealed that the Mean colour perceptibility tolerance for which 50% of the dentist observers could perceive a colour difference (50/50 perceptibility) was 2.6 ΔE units. The predicted colour difference at which 50% of the subjects would remake the restoration due to colour mismatch (clinically unacceptable colour match) was 5.5 ΔE.

Griggs *et al* (2007)[33] explains about the recent advances in materials for all-ceramic systems restoration that mimic the appearance of the natural teeth .He summarises the method of ceramic fabrication such as powder condensation, slip casting, heat pressing and CAD-CAM manufacturing . Interpretation of variety of invitro studies pertaining to mechanical reliability, marginal adaptation or bonding to resin cements, various processing protocols and survival probabilities of all-ceramic veneers ,inlays , onlays ,crowns and fixed partial dentures are discussed in this review.

Della Bona *et al*(2008)[24] explains a comprehensive review about the clinical evidence for the treatment of natural teeth using all-ceramic restorations .The study suggested the use of any all-ceramic system for veneers, intra-coronal restorations and complete-coverage restorations for single-rooted anterior teeth while Molar restorations include those made of alumina and increasingly, zirconia and bonded lithium disilicate. Reasonable evidence has shown the effectiveness of anterior three-unit fixed partial dentures made from lithium disilicate, alumina and zirconia. For three-unit restorations in posterior regions, expert consensus suggests that only zirconia-based systems are indicated.

Volpato *et al* (2009)[71] describes the **i**nstrumental analysis of the optical influence of illuminants like daylight (D65), incandescent light (A) and fluorescent light (F6), substrates (composite resin; silver–palladium alloy and gold) and different ceramic thickness (1.5mm/2mm and 2.5 mm) on the final colour of IPS-Empress and IPS-Empress 2 systems. The study concluded that when the substrate presents a colour very similar to the ceramic, the thickness of 1.5mm can be utilized for any of the systems tested and if there are metallic posts and cores present, it becomes necessary to create enough space to mask the substrate and to select a restorative system that presents a ceramic substructure.

Chu *et al* (2010)[16] reviewed the current status of hand held systems for tooth colour matching. The study revealed that Spectrophotometers, colorimeters and imaging systems are useful and relevant tools for tooth colour measurement, analysis and for quality control of colour reproduction. Different measurement devices either measure the complete tooth surface providing a ‘‘colour map’’ or an ‘‘average’’ colour of the limited area [3–5 mm] on the tooth surface. These instruments are considered to be useful tools in colour analysis for direct or indirect restorations, communication for indirect restorations, reproduction and verification of shade. Whenever possible, both instrumental and visual colour matching method should be used, as they complement each other and can lead towards predictable esthetic outcome.

Denry *et al* (2010)[25] gives a systematic review on the evolution of ceramics from feldspathic porcelains to zirconia-based all-ceramics, tremendous progress has been made in terms of mechanical performance, with a ten-fold increase in flexural strength and fracture toughness. The author enumerates on the broad classification of dental ceramics into metal-ceramic and all-ceramic systems, its composition and their different fabrication techniques. The author explains the common important characteristics of all-ceramic systems, such as the proportion of glassy phase and amount of porosity and their influence on optical and mechanical properties.

Shao *et al* (2010)[58] evaluated the effect of 18-8 nichrome alloy, and Bio Herador N bio-type noble metal-ceramic alloy and A2 colour photo-curing compound resin materials colour on the chromatic value of In-Ceram zirconia core, Cercon base zirconia core, and Cercon base colour zirconia core at thickness 0.5±0.01mm and Empress II at 0.8±0.01mm .The colour difference of Empress II samples was more than 1.5 among the background colour groups, while that of Zirconia was less than 1.5. The influence of background colour on the Empress II dentin was visible, such that it can be used on a tooth colour post. The influence of background colour was invisible for the three kinds of Zirconia core materia1s, exhibiting excellent masking abilities and could be used on any colour background.

Azer *et al* (2011)[5] evaluated the effect of overall colour change of IPS Empress ceramic laminates of 0.5mm thickness resulting from applying shades light (A3) and dark (C4) of composite resin substrate material, over two shades of ceramic material, translucent (T1) and opaque (O2). The ceramic discs were cemented to resin discs with a clear resin cement. This study suggest that the colour of the supporting composite resin substrate clinically influence the overall selected colour of 0.5 mm ceramic laminate veneers, regardless of the ceramic material shade.

Chaiyabutr *et al* (2011) [10] evaluated the resulting optical colour of a CAD/CAM glass-ceramic lithium disilicate-reinforced crown due to the effect of tooth abutment colour, cement colour and ceramic thickness of 1mm,1.5mm, 2mm and 2.5mm. The study revealed that a dark-coloured abutment tooth demonstrated the greatest ΔE values compared to other variables tested. For dark-coloured abutment teeth, crowns with a ceramic thickness of 1.0 mm cemented using either translucent cement or opaque cement and crowns with a ceramic thickness of 1.5 mm cemented with translucent cement resulted in within a clinically unacceptable range in terms of colour change ($\Delta E>3.7$).

Cubas *et al* (2011)[20] assessed the influence of varying ceramic thicknesses and luting agents on colour variation of Vitadur- Alpha ,Noritake Super Porcelain EX-3 , Vision-Esthetic ,IPS Classic ,All Ceram and Vintage Halo veneering ceramics, with Resin composite discs (Z-250, shade C4) used as bases to simulate a chromatic background. The study revealed that 2-mm thickness with opaque cement presented the strongest masking ability of a dark coloured background when compared to a non- opaque luting agent and the other thicknesses tested.

Kelly *et al* (2011) [40] explained the history of dental ceramics ,the thermal expansion of porcelains for metal ceramics machining and CAD/CAM as fabrication methods for clinical restorations, fit of ceramic restorations, clinical failure mechanisms of all-ceramic prostheses, chemical and thermal strengthening of dental ceramics, intraoral porcelain repair and the criteria for selection of various ceramics available. It is found that strong scientific and collaborative foundations exist for the continued.

Kilinc *et al* (2011) [41] evaluated the resin cement colour stability and its effect on the final shade of the all-ceramics. Adhesive resin cements may undergo internal discolouration, which may be seen through , affecting the appearance of translucent all-ceramic restorations. Light cure resin cements are recommended mostly for anterior restorations due to better colour stability. The ceramics luted with Dual Cured resin cement groups showed findings of more colour change because of the oxidation of reactive groups in amine accelerators and inhibitors affecting the aesthetics of final restoration margins if directly exposed.

Turgut *et al* (2011)[68] assessed the effect of different shades of light cured Variolink Veneer (+3, MO, -3); Rely X Veneer,A1, A3, White Opaque, Translucent; and dual cured Maxcem Elite (White, Yellow, White Opaque, Clear) and Variolink II, (White Opaque, Translucent) resin cements and UV ageing on the colour of A1, A3, HO and HT shades of IPS e.max Press full ceramic laminates. Colour Difference was due to discolouration of resins which becomes more important beneath the thinner 0.5– 0.9 mm and more translucent Porcelain Laminate Veneer restorations, that may affect the long-term success of Porcelain laminate veneers restorations .Colour changes in restorative materials induced by UV irradiation have been related to chemical alterations in the initiator system, activators and the resin. The author also concluded that the discolouration observed after the ageing process was within a clinically acceptable level.

Vichi *et al* (2011)[70] explains about the difficulty in shade match due to varied optical properties of tooth colour. Colour match between natural dentition and restoration or prosthesis is a complex process which consists of two specific procedures: colour selection and colour reproduction .The author explains the advantages of spectrophotometer over visual assessment. Colour selection has advanced through the development of new shade guides and electronic shade taking devices, although visual assessment has still not been entirely replaced by electronic instrumentation.

Aiqahtani *et al* (2012)[1] evaluated the colour difference (ΔE) of three different ceramic materials (IPS Empress Esthetic Press, IPS Empress e.max Press, IPS Empress ZirPress from standard (on substrate without cement) and when different shades of light-polymerizing Translucent, White Opaque, B0.5, A1, and A3 of RelyX™ Veneer were used under two different thicknesses (0.5 mm and 0.7 mm) . ΔE was higher for leucite reinforced glass-ceramic (IPS Empress Esthetic) followed by fluorapatite glass-ceramic (IPS Empress ZirPress) and lowest mean ΔE values were for lithium disilicate glass-ceramic. Mean values of ΔE decreased when the thickness of ceramic increased from

0.5 mm to 0.7 mm. It was observed that the White Opaque had significantly increased *ΔE* values when compared with (TR, B 0.5, A1, and A3)

Shono *et al* (2012)[60] evaluated the contrast ratio (CR) and masking ability of IPS e.max Press, VitaVM7 and Nobel Rondo Press Alumina(NRPA) veneering ceramics at 1mm/1.5mm thicknesses by measuring the colour differences over white and black backgrounds . NRPA demonstrated the least masking ability among the three ceramics tested. IPS emax and VM7 had similar masking abilities, but IPS emax exhibited higher CR percentages than VM7. All the materials tested in this study were not capable of completely masking the underlying black background, although the masking ability improved when the thickness was increased from1.0 to 1.5 mm.

Zhou *et al* (2012)[73] evaluated the ability to mask a dark background such as a dark tooth or core buildup material of IPS e.max all-ceramics system of HO series. The colour differences of ceramic disks with the thicknesses of 0.6mm and 0.8mm were undistinguishable by the human eyes resulting in esthetic restorations. While the thickness of 0.4mm and 1.0mm ones were distinguishable implied to a reluctant outcome. Specimens with the thickness of 1.0mm could prevent metal substrate colour transmitting through the cylindrical specimens, but resulted in an unesthetic outcome.

Niu *et al* (2014) [48] evaluated the effects of different colour and opacities of three cement thicknesses on the shade matching of machinable lithium disilicate restorations luted on silver-palladium (Ag-Pd) foundations.

White opaque (Nexus) cement at 100- µm cement-film thickness resulted in the best colour match with colour difference below the clinical perceptible threshold ($\Delta E < 2.6$) relative to the target block. Increasing the cement thickness above 100 µm did not improve the shade match. Nexus3 white opaque at all thicknesses and Multilink white opaque at 50 µm resulted in the best shade matches

Chen *et al*(2015)[12] evaluated the effect of Variolink Veneer, shades LV-3, LV-2, MV, HV + 2, HV + 3; Panavia F, shades light and brown; and RelyX TM Veneer, shades WO, TR, A3 resin cement on the final colour of IPS emax Press, LT A3 shade ceramic veneer .A spectrophotometer (VITA Easyshade) was used to measure the colour parameters (CIE L*a*b* values).The study revealed that different shades of resin cement produced obvious effects on the final colour of ceramic veneers, the resin cement shades HV + 3 and WO can increase the brightness resulting in ΔE values more than 3.3 and reduce the chroma of ceramic veneers, whereas the resin cement shades LV-3 and brown tend to increase the chroma.

Shadman *et al* (2015)[57] conducted a study to determine the minimum thickness of a multilayer porcelain restoration required for masking severe tooth discoloration. IPS e.max Press of different thicknesses (core/veneer) 0.4/0.4 mm,0.5/0.5 mm, 0.6/0.6 mm and 0.8/0.7 mm against backgrounds, C4-shade body porcelain and an opaque background were fabricated to mimic a discoloured or stained natural tooth structure . ΔE of all groups were within the range of the clinically acceptable colour difference ($\Delta E \leq 3.3$), thus all the groups could mask the C4 background including group 1 with only 0.8 mm thickness. The author concluded that the minimum thickness of a multilayer porcelain restoration (IPS e.max Press) required for masking severe tooth discolouration was 0.8 mm including a 0.4 mm core and 0.4 mm veneer

Dede *et al* (2016)[23] evaluated the effects of A1, A2, A3, B2, C2 composite resin foundation and shades of Translucent (Tr), Universal (Un=A2), and white-opaque (Wo) resin cement materials on the colour of medium-opacity and high-translucency lithium disilicate ceramics . The author revealed that when translucent and universal cement shades were used, the core shade did not affect the final colour of the ceramics. White opaque cement caused clinically unacceptable colour changes in both ceramics on all shades of CRFs except the C2 CRF and when high translucency ceramic was used on the A2 CRF. These changes were clinically acceptable, but perceptible.

Pande *et al* (2016)[50] evaluated the shade replication of a pressable all-ceramic system of different opacities when placed on stained and unstained extracted natural tooth. The shade reproduction of Group I ‐ LT (Us.T.) was the best among all the groups, so can be used for restorations on unstained tooth. The shade reproduction of Group II ‐ MO (Us.T.) and Group II ‐ MO (S.T.) was advantageous, so may be used on unstained as well as on stained tooth . The shade reproduction of Group III ‐ HO (S.T.) was not within acceptable range and hence the clinical implication of Group III – HO may be limited to be applied over intensely stained tooth.

Perroni *et al*(2016)[52] evaluated the influence of different shades of flowable resin composite A1, A2, B1, white opaque or translucent on the final shade of monolithic (enamel E1.0 or dentin D1.0) and bilayer (E0.5 D0.5) feldspathic porcelain over A2 and B1simulated dental substrate . Porcelain veneer E1.0 groups were the most translucent, while the pairs veneer with luting agent WO showed the lowest translucency, and A1,A2,B1, and IL yielded little to no differences in translucency of the pairs. The overall best shade matching with A2 substrate was observed for D1.0 veneer and WO luting agent.

Pires *et al* (2016)[53] evaluated the effect of the substrate, cement, type, and thickness of the ceramic on the resulting colour of IPS e.max Press LT (low translucency) and HO (high opacity) at thicknesses (1.5 and 2 mm) .The study revealed that the substrate colour, type and thicknesses of ceramic and the presence of cement significantly influenced the resulting optical colour with the ΔE values of cemented HO ceramics lower than those of the LT ceramic. On a metallic alloy substrate, the ceramic crown should be fabricated only with high opacity ceramic. The translucent ceramic is indicated for dentin or resin substrate.

Basso et al(2017) evaluated the masking ability and translucency of monolithic HT and LT of lithium disilicate ceramic (IPS e.max CAD) of thickness (0.7,1,1.5 and 2mm) and bilayer IPS e.max Zir CAD ceramic structures(0.5 mm thick zirconia framework with CAD-CAM lithium disilicate veneer) against a typical dental shade substrate (A2) and discoloured backgrounds (shade C4, coppery, and silvery). The study revealed that as thickness of lithium disilicate ceramic reduces, its translucency parameter and colour difference increased. Monolithic CAD –CAM lithium disilicate masked tooth coloured substrate better than metallic backgrounds. Bilayer ceramic structures, improved masking over all evaluated substrates.

Leevailoj *et al* (2017)[43] examined the influence of material type, thickness, and substrate colour on the masking ability of IPS emax lithium disilicate glass ceramic ,high-translucent zirconia and high-translucent zirconia with liner ceramics over white ,black ,metal and resin composite shades A2 ,A3 and C 4. Both contrast ratio and masking ability increase as thickness increased. A darker substrate colour reduced the masking ability of ceramics when compared with a lighter- colour substrate. For improved masking ability, high opaque IPS e.max Press is recommended over Lava Plus and Lava Plus/Liner for the masking of dark substrates.

Tabatabaian *et al* (2017)[65] studied the masking ability of zirconia copings against different composite shades ,A3 shade zirconia, Nickel –Chromium alloy, non –precious gold coloured alloy, amalgam ,black and white. The colour difference was evaluated between CIE Lab values of specimens against A2 and other substrates .The study revealed greater colour difference for black and white backgrounds than for tooth–coloured and metal alloy backgrounds .The author concluded that the best method of masking the background colour was to use zirconia coping with a proper thickness. To achieve ideal masking, the minimum thickness of a zirconia coping should be 0.4 mm for A1 ,A3.5 shade composite resin, A3 shade zirconia and nonprecious gold-coloured alloy, 0.6 mm for amalgam, and 0.8 mm for nickel-chromium alloy.

Skyllouriotis *et al* (2017)[61] studied the translucency parameters (TPs), contrast ratios (CRs) of 6 veneer restorations such as Vitablocks Mark II, IPS e.max CAD LT , IPS e.max CAD HT (EMXC HT) ,IPS Empress CAD LT (EMP LT) , IPS e.max Press LT (EMXP LT) and CZR and their potential to mask dark tooth colours. CR values of EMXP LT were significantly higher than those of the other tested materials. TP values over black and white backgrounds of VMII and EMXC HT were significantly higher than those of the other tested materials. All tested ceramics exhibited poor masking properties against the A4 background. The colour differences of most tested ceramics were more acceptable when tested against the B4 background.

Materials and Methods

MATERIALS AND METHODS

This *in vitro* study was conducted to comparatively evaluate, the masking ability of lithium disilicate ceramic with different core thickness on the shade match of indirect restorations over metallic substrate.

The following materials, instruments and equipments were used in the present study:

Materials used:

- Acetyl sheet of thickness - 1mm/1.3mm/1.6mm/2.5mm (Plastic house, Paris,chennai) (Fig.1)
- Sprue wax 3mm diameter (Bego, Germany) (Fig.2)
- Surfactant spray (Aurofilm, BEGO, Germany) (Fig.3)
- Phosphate bonded investment material (Bellavest SH, Bego, Germany) (Fig.4)
- Colloidal silica (Begosol, BEGO, Germany) (Fig.5)
- Distilled water (Merck & Co., Mumbai India) (Fig.6)
- Low translucency Lithium disilicate pressable ingots (Ivoclar vivadent, USA) (Fig.7)
- Invex liquid (Ivoclar vivadent, USA) (Fig.8)
- Silicon carbide emery papers (3M India Ltd., Bangalore, India) (Fig.9)
- Nickel Chromium casting alloy pellets (Bellabond plus BEGO, Germany) (Fig.10)

- Aluminium oxide 50 µm (Korox, Alpha bond, Australia) (Fig.11)
- White background (A4 Sheet-JK copier) (Fig.12)
- Polyvinylsiloxane impression material (Variotime putty, Kulzer, Germany) (Fig.13)
- Hydrofluoric acid 10% (IPS Ceramic etching gel, Ivoclar vivadent, USA) (Fig.14)
- Brass sheet 40µm (Fig.15)
- Resin luting cement (Maxcem Elite, Kerr, USA) (Fig.16)

Instruments used:

- PK Thomas instruments (Fig.17)
- Silicon Investment ring system for emax press (Ivoclar vivadent, USA) (Fig.18)
- Alox plunger (Ivoclar vivadent, USA) (Fig.19)
- Fine diamond disc (Dentorium, New York, U.S.A) (Fig.20)
- Crucible former and Silicone casting rings for metal casting (Siliring, Delta labs, Chennai, India) (Fig.21)
- Metal separating disc and mandrel (Dentorium, New York, U.S.A) (Fig.22a & b)
- Tungsten carbide bur (Edenta, Switzerland) (Fig.22c)
- Metal rings (Fig.23)
- Scissors, Probe and Tweezer (Fig.24)
- Air tight Dark container (Fig.25)

Equipments Used:

- Hand Press machine (Indian Tools Corp) (Fig.26)
- Vacuum mixer (The Continental, Whip Mix, Kentucky ,USA) (Fig.27)
- Burnout furnace(Technico laboratory Products Pvt. Ltd.) (Fig.28)
- Heat press furnace -Programat EP 3000 (Ivoclar vivadent, USA) (Fig.29)
- Induction casting machine (Fornax GEU, BEGO, GERMANY) (Fig.30)
- Sandblaster (Delta labs, Chennai, India) (Fig.31)
- Alloy grinder (Demco, California, U.S.A.) (Fig.32)
- Digital Vernier caliper (Mitutoyo, Japan) (Fig.33)
- Digital Micrometer (Mitutoyo, Japan) (Fig.34)
- Digital Ultrasonic cleaner (Beijing Ultrasonic Co., China) (Fig.35)
- Light curing unit (3M ESPE) (Fig.36)
- Spectrophotometer (CM 3600d) (Fig. 37)

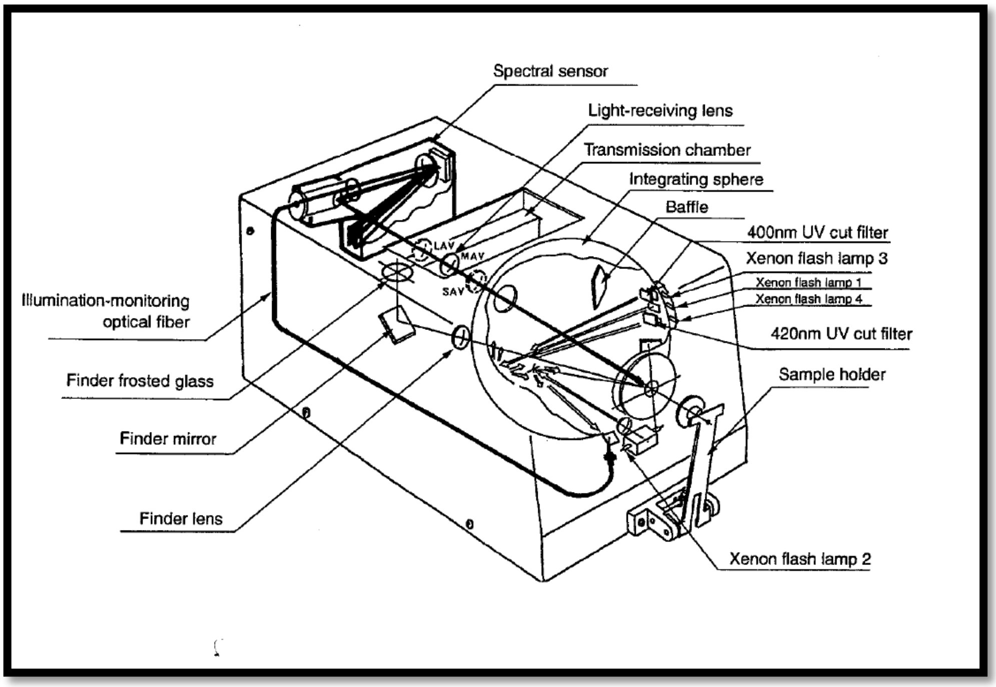
Description of Spectrophotometer: (Fig.37)

The colour of the ceramic disc specimens over, white background and Ni-Cr metal substrate, before and after cementation, were analysed using CM-3600d spectrophotometer. JAYPAK 4808 software was used to analyse the data. CIE Illuminant D 65 was used in all colour measurements. CIELAB (1976) colour space was used for the colour measurements. White and Black tiles were used as standards for calibrating the instrument.

Model	CM3600d
Illumination/viewing system	Reflectance: d/8(diffused illumination, 8-degree viewing)
Light-receiving element	Silicone photo diode array(dual 40 elements)
Spectral separation device	Diffraction grating
Wavelength range	360nm-740nm
Wavelength pitch	10nm
Reflectance range	0to 200%; resolution 0.01%
Light source	Pulsed xenon lamps(x4)
Measurement time	Approx 1.5 seconds
Power	100-200V, 50-60Hz 25W AC

Diffused Light from the pulsed xenon lamps, reflected from the inner surface of the integrating sphere illuminates the specimen uniformly. The light reflected from the surface of specimen at angle of 8° is then received by the specimen measuring optical system and the diffused light in the integrating chamber received by the illumination-monitoring optical fiber are guided to the sensor. In the sensor, the light in the wavelength range of 360-740 nm is divided into 10 nm-pitch components and is projected onto the sensory array sections, which convert the light into proportional current and direct the current to the analog processing circuit. The spectrophotometer is connected to a computer which has a software installed JAYPAK 4808 to analyse the data.

Line diagram of Spectrophotometer:



METHODOLOGY

This *in vitro* study was conducted to comparatively evaluate, the masking ability of lithium disilicate ceramic with different core thickness on the shade match of indirect restorations over metallic substrate.

The methodology adopted in the present study is described under the following sections:

I Fabrication of custom metallic mold.

II Fabrication of plastic patterns for lithium disilicate ceramic discs and Ni-Cr metal discs:

A. Fabrication of plastic patterns for lithium disilicate ceramic discs.

B. Fabrication of plastic patterns for Ni-Cr metal discs.

III Fabrication of Heat pressed ceramic discs:

A. Investing of patterns.

B. Heat pressing.

IV Grouping of lithium disilicate ceramic discs.

V Fabrication of Ni-Cr metal discs:

A. Investing and casting of plastic patterns.

B. Finishing and surface treatment of Ni-Cr metal discs by sandblasting.

VI Grouping of Ni-Cr metal discs.

VII Evaluation of colour measurements of Lithium disilicate ceramic discs against white background.

VIII Evaluation of colour measurements of Lithium disilicate ceramic discs against Ni-Cr metal discs before cementation.

IX Cementation of Lithium disilicate ceramic discs to Ni-Cr metal discs using resin cement.

A. Surface preparation of lithium disilicate ceramic discs.
B. Fabrication of a metallic template to standardize the cement thickness at 40 microns.
C. Cementation of ceramic discs to Ni-Cr metal disc.
D. Light polymerization.
E. Storage of cemented lithium disilicate ceramic disc-Ni-Cr metal disc in distilled water.

X Evaluation of colour measurements of lithium disilicate ceramic discs against Ni-Cr metal discs after cementation.

XI Measurement of colour difference (ΔE).

XII Data tabulation and statistical analysis

I) Fabrication of custom metallic mold: (Fig.38-39)

A custom made metallic mold (Fig.38, 39) was used to obtain plastic disc patterns of 10mm diameter, for fabricating Lithium disilicate ceramic discs and Ni-Cr metal discs specimens. The custom metallic mold is a two piece unit consisting of a base (Fig.39A) with a central orifice measuring

10mm in diameter and an upper counterpart (Fig.39B). The upper counter part consists of 4 pivots and a plunger. The pivots facilitate the plunger to penetrate the orifice situated in the base when held in the hand press machine (Indian Tools Corp) (Fig.26).

II. Fabrication of plastic patterns for lithium disilicate ceramic discs and Ni-Cr metal discs: (Fig: 40-42)

A. Fabrication of plastic patterns for lithium disilicate ceramic discs: (Fig: 40-42)

The acetyl plastic sheets of thickness 1mm/1.3mm/1.6mm (Plastic house, Paris) (Fig.1) were selected to fabricate plastic patterns for Lithium disilicate ceramic discs. The acetyl plastic sheet was placed between the base and the upper counter part of the metallic mold, when the entire assembly was placed on to the hand press machine (Fig.40). On activation, the plunger penetrated the acetyl plastic sheet and produced plastic disc patterns (Fig.41). Thus, 10 discs for each thickness were obtained making a total of 30 plastic disc patterns, for the fabrication of the Lithium disilicate ceramic discs (Fig.42 a, b, c).

B. Fabrication of plastic patterns for Ni-Cr metal discs : (Fig: 40-42)

The acetyl plastic sheet of 2.5mm thickness (Plastic house, Paris) (Fig.1) were selected to fabricate plastic patterns for Ni-Cr metal discs. The acetyl plastic sheet is placed between the base and the upper counter part of the metallic mold when the entire assembly was placed on to the hand press machine (Fig.40). On activation, the plunger penetrated the acetyl plastic sheet and produced plastic disc patterns (Fig.41). Thus 30 plastic disc patterns were obtained for the fabrication of metal substrate (Fig.42d).

III. Fabrication of Heat pressed ceramic discs :(Fig. 43-56)

A) Investing of patterns: (Fig.43-48)

The dimensions of the plastic patterns for fabrication of ceramic discs were verified with the help of digital vernier caliper (Mitutoyo, Japan) to 10mm diameter and thickness 1mm/1.3mm/1.6mm (Fig.33, 43-46). A sprue wax of 3mm (Bego, Germany) (Fig .2) was attached on the edge of the plastic disc patterns at an angle of 45° to the investment ring base (Fig.47a, 47b). The patterns were widely spread at a distance of 3mm. The sprued patterns were coated with surfactant spray (Aurofilm, BEGO, Germany) (Fig.3) to improve the wetting of the pattern.

These patterns were invested with phosphate bonded investment material (Bellavest SH, Bego, Germany) (Fig.4) according to manufacturer's instructions using IPS silicone investment ring (Siliring, Delta labs, Chennai, India) (Fig.18) positioned on the investment ring base without distorting the patterns (Fig.47c). After complete setting of the investment material, the silicon ring was separated and the investment mold was kept ready for burnout (Fig.48).

B) Heat pressing :(Fig: 49-52)

On completion of the preheating cycle, the investment mold was removed from the burnout furnace (Fig.28) and the cold Low translucency Lithium disilicate Pressable ingot (Ivoclar vivadent, USA) (Fig.7) was positioned into the hot investment mold (Fig.49) with the help of IPS e.max Alox plunger (Fig.19, 50).The investment mold is placed in the heat press furnace (Fig.29) and programmed to obtain heat pressed ceramic discs (Fig.51). Thus the patterns were invested, heated and pressed (Fig.52a) in accordance with the manufacturer's instructions. Investment mold is bench cooled and divested with glass beads. The reaction layer formed on the ceramic surface was ultrasonically cleaned in Invex liquid (Ivoclar Vivadent, USA) (Fig.8) for 10 minutes, which contains <1% hydrofluoric acid followed by complete removal of the reaction layer from the contact surfaces using Al_2O_3 at 1–2 bar pressure (15–30 psi). The ceramic discs were separated using a fine diamond disc (Dentorium, New York, U.S.A) (Fig.20, 52b). Finishing of ceramic discs was done using silicon carbide sheets of different grits (3M India Ltd., Bangalore, India) (Fig.9 &52c).The thickness of all the finished ceramic discs were verified with a digital vernier caliper.

IV. Grouping of lithium disilicate ceramic discs: (Fig: 53-56)

The 30 Lithium disilicate discs were then divided into three groups of 10 each with diameter 10mm (Fig.53) and varying core thickness

Group I: 1mm thickness of Lithium disilicate discs (n=10). (Fig.54a, 54b)

Group II: 1.3mm thickness of Lithium disilicate discs (n=10). (Fig.55a, 55b)

Group III: 1.6mm thickness of Lithium disilicate discs (n=10). (Fig.56a, 56b)

V. Fabrication of Ni-Cr metal discs: (Fig.57-62)

A) Investing and casting of plastic patterns: (Fig: 57-61)

The dimensions of the plastic patterns for fabrication of metal discs were verified to 10mm diameter and thickness of 2.5mm with the help of a digital vernier caliper. (Fig.57)

The plastic patterns were attached with a preformed wax sprue of 3mm diameter (Fig.58). The patterns were evenly spread at an angle of 45-degree to the runner bar for the uninterrupted flow of the molten metal, which at its apex was attached to the crucible former. The sprued patterns were coated with surfactant spray to improve the wetting of the pattern.

This whole assembly of 10 sprued plastic patterns was invested with phosphate bonded investment material in the casting ring (Siliring, Delta labs, Chennai, India) (Fig.21). The investment with powder liquid ratio (160grams powder: 37ml liquid) was used according to manufacturer’s instructions. Mixing was done using vacuum mixer (The Continental, Whip Mix, Kentucky, USA) (Fig.27) for 60 seconds before pouring the investment (Fig.59a, 59b). After 20 minutes of bench setting time, the silicone ring was removed. The set investment was placed in a burnout furnace (Technico, Ind Products, Chennai) in a position with the crucible end contacting the floor for escape of melted wax. The wax patterns were subjected to pre-heating technique in the burnout furnace at temperature of 450°C for 30 minutes (Fig.60a). Then the investment mold was continuously heated to 950°C at the rate of 8C°/min in the burnout furnace (Fig.60b). The investment mold was kept in the induction casting machine (Fornax GEU, BEGO, GERMANY) (Fig.30) (Fig.61a) and aligned such that the sprue hole was approximating the ceramic crucible. Three Ni-Cr casting alloy pellets (Bellabond plus BEGO, Germany) (Fig.10) were placed in the crucible and the counterweight was balanced. The casting temperature of the alloy was adjusted to 1500 °C. Once the alloy had melted, the lever was released to cast the metal into the mold. In this manner thirty metal substructures were obtained (Fig.61b).

B) Finishing and surface treatment of Ni-Cr metal discs by sandblasting: (Fig.62)

After bench cooling, the castings were divested (Fig.62a) and the residual surface investments were removed by means of a sandblaster (Delta labs, Chennai, India) (Fig.31) using 50µm aluminium oxide (Korox, Alpha bond, Australia) (Fig.11,62b)

Sprues were severed by means of carborundum discs (Dentorium, New York, U.S.A) and nodules were removed by tungsten carbide bur (Edenta, Switzerland) (Fig.62c). The surface of metal to be luted with the resin cement, was cleaned with pressurized steam for removal of any surface contaminants using a steam cleaner. The average thickness of the metal was adjusted to 2.5mm. The surface was air abraded with 50 µm aluminium oxide at 75 psi pressure.

VI. Grouping of Ni-Cr metal discs :(Fig . 63)

Thirty Ni-Cr metal substructures were obtained. 10 metal discs were randomly assigned to each group of lithium disilicate ceramic. (Fig.63)

VII. Evaluation of colour measurements of lithium disilicate ceramic discs against a white background: (Fig.64a, 64 b)

The specimens were placed against a standard white background (A4 Sheet-JK copier) (Fig.12 & 64a) and the colour parameters (L*a*b) of the specimens were determined with CM-3600d spectrophotometer (Fig.37) in wavelength 360-740 nm. The L^*, a^*, b^* parameters were measured according to Commision Internationale de I'Eclairage (CIE) using D 65 illuminant and observer function at 10°. (Fig.64b)

VIII. Evaluation of colour measurements of lithium disilicate ceramic discs against Ni-Cr metal discs before cementation: (Fig: 65-66)

The colour parameters of the Lithium disilicate ceramic discs when placed over Ni-Cr metal substrates was to be determined. The metal discs were embedded in putty (Polyvinylsiloxane impression material (Variotime putty, Kulzer, Germany) (Fig.13) held by a metal ring (Fig.23,65a). A drop of distilled water with refractive index of 1.7 was placed between the discs when they were brought together so that a good optical contact is possible during the spectrophotometric measurement. (Fig.65b).The optically connected ceramic disc and metal disc were embedded within silicone putty in a metal ring to avoid the influence of external light. The colour coordinates (L*a*b*) were determined with CM-3600d spectrophotometer in wavelength 360-740 nm. The L^*, a^*, b^* parameters were measured according to Commision Internationale de I'Eclairage (CIE) using D 65 Illuminant and observer function at 10° (Fig.66).

IX. Cementation of lithium disilicate ceramic discs to Ni-Cr metal discs using resin cement: (Fig.67-77)

A) Surface preparation of lithium disilicate ceramic discs: (Fig.67, 68)

The ceramic discs were placed in an ultrasonic cleaner(Beijing Ultrasonic Co., China) (Fig.35) for 10 min (Fig.67) and etched with 10% hydrofluoric acid(IPS Ceramic etching gel ,Ivoclar vivadent, USA)(Fig.14)for 30 sec (Fig.68a).Then the discs were rinsed with water spray for 1 min (Fig.68b) followed by air drying (Fig 68c, 68d). Thus 30 ceramic disc samples were surface treated before the commencement of luting.

B) Fabrication of a metallic template to standardize the cement thickness at 40 microns: (Fig: 69,70)

A custom-made metallic template was used to ensure the space required for the luting cement. It consists of a base engaged to an upper counter (Fig.69, 70).The base was provided with slots for engaging the spacer.

C) Cementation of ceramic discs to Ni-Cr metal discs: (Fig.71-74)

A brass sheet of 40 µm thick (Fig.15) verified using digital micrometer (Mitutoyo, Japan) (Fig.34) was used as a spacer (Fig.71). The metal disc was stabilised within the orifice in the base of the template (Fig.72). The brass sheet was held in position by the space created at the three corners of the base engaging the upper counter (Fig.73). The resin luting cement (Maxcem Elite, Kerr, USA) (Fig.16) was delivered using automix system (Fig.74a) on to the sandblasted Ni-Cr metal disc substrate and over this the ceramic disc was placed (Fig.74b) and held with finger pressure to maintain the cement thickness at 40µm (Fig.74c).

D) Light polymerization: (Fig.75, 76)

The resin cement is a dual cure, self etching, self adhesive cement and hence it was tack cured for 3 sec (Fig.75a) using light cure unit (3M ESPE) (Fig.36) and the excess cement was removed from the edges with a straight probe (Fig.24) followed by 40 sec of light curing (Fig.75b). The maintenance of the luting space was verified on removing the assembly from the template (Fig.76).

E) Storage of cemented lithium disilicate ceramic disc-Ni-Cr metal disc in distilled water: (Fig.77)

The cemented lithium disilicate disc-Ni-Cr metal disc assembly was then suspended in distilled water for 24 hrs in a closed air tight dark container (Fig.25) to allow complete polymerization before the commencement of spectrophotometric analysis (Fig.77). The same procedure was followed for all the 30 test specimens.

X. Evaluation of colour measurements of lithium disilicate ceramic discs against Ni-Cr metal discs after cementation: (Fig: 78-81)

Following complete polymerization, the cemented ceramic specimen was embedded within putty in a metal ring, to avoid the influence of external light. The colour parameters of the Lithium disilicate discs after cementation (Fig: 78-81) was measured with CM-3600d spectrophotometer in wavelength 360-740 nm. The L^*, a^*, b^* parameters were measured according to Commision Internationale de I'Eclairage (CIE) using D 65 Illuminant and observer function at 10°.

XI. Measurement of colour difference:

The CIE system of colour specification provides a common means of analysing and presenting colour measurement data. To specify a particular object's colour, the spectral distribution of light reflected from the object must be known and that spectral reflectance must be averaged by three weighing functions called the colour matching functions and they characterise the colour matching properties of an average observer with normal colour vision, known as the 1931 CIE standard observer. They are weighed by relative spectral power distribution of CIE standard illuminants. The resultants Tristimulus X, Y, Z are then the standard response of the eye to the red, green and blue stimuli from the object.

Knowing the tristimulus values for a particular specimen is beneficial in terms of labelling its colour. In discussing the colour difference between objects, CIELAB system can be employed. The magnitude and direction or shift of the difference between two colour stimuli can be identified.

L* defines lightness,

a* denotes the red/green value

b* denotes the yellow/blue value.

The colours of each opponent pair are indicated by the positive and negative values of a* and b*.

Calculation of (CIELAB) L* , a* and b*:

The L*, a*and b* values are derived from the tristimulus values X, Y and Z by using CIE 1976 CIELAB equation

$L^* = 116\ (Y/Y_n)^{1/3} - 16$

$a^* = 500[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}]$

$b^* = 200[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}]$

where X_n, Y_n and Z_n are the tristimulus values of reference white. For D 65 illumination at 2° observer $X_n = 95.01, Y_n = 100.0$ and , $Z_n = 108.82$.

In the CIELAB system, the total colour difference ΔE combines the difference of three independent variables such as:

The lightness, represented in the L *axis

Minimum value means a shift to darker (black)

Maximum value means a shift towards lighter (white)

Along the a* axis, value in the positive direction depicts a shift toward red, value in the negative direction depicts a shift toward green.

Along the b* axis, value in the positive direction depicts a shift toward yellow, value in negative direction depicts a shift toward blue.

At the centre of this plane it is neutral or gray.

These formulas, as well as those for determining as perceiving colour difference between the two objects (ΔE) as follows

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

ΔL- difference in lightness

Δa -difference in a coordinates

Δb -difference in b coordinates

ΔE –total colour difference

The expressions for these colour differences are ΔL^* Δa^* Δb^* (Δ symbolizes “delta,” which indicates difference).

CM-3600d spectrophotometer was used to analyse the colour difference. The system was connected to the computer. The target mask was selected based on the specimen and application. The system was calibrated with a white calibration plate and zero calibration plate. The specimen was held against a white background with the help of a sample holder and the L^* a^* b^* values were displayed in the system. Then following the cementation of the metal discs to the ceramic discs the colour coordinates were measured by placing the sample within a putty mold to avoid the influence of external light. The colour difference was measured by the following formula

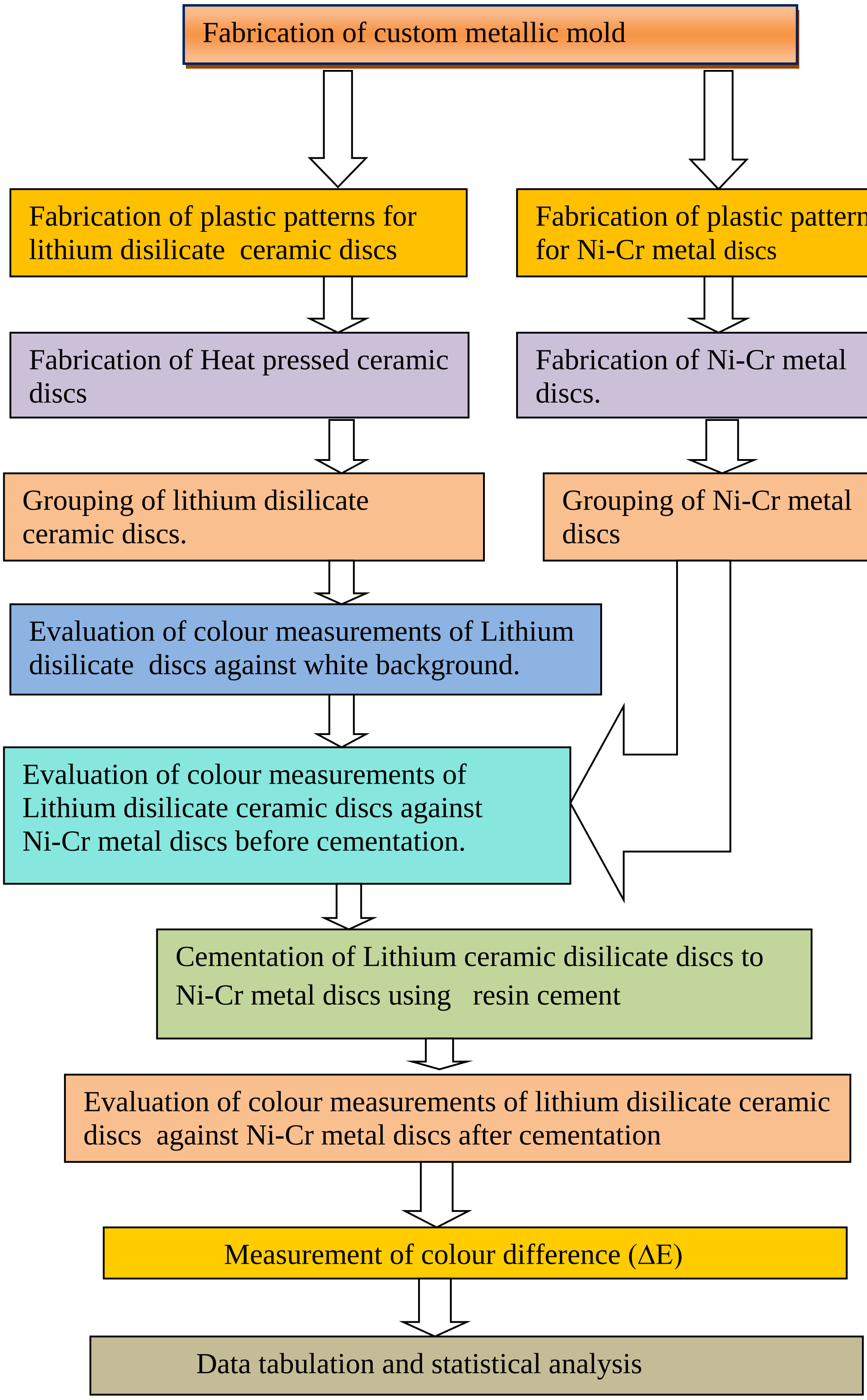
$$\boldsymbol{\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}.}$$

XII. Data tabulation and statistical analysis:

The results obtained were tabulated and the data was subjected to statistical analysis using the SPSS-16 software.

ANNEXURE I

METHODOLOGY OVERVIEW



Figures

ANNEXURE II

FIGURES

MATERIALS

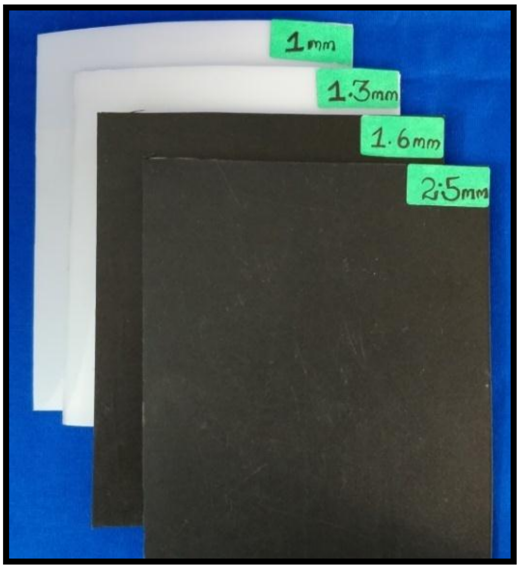


Fig.1: Acetyl sheets of thickness (1mm/1.3mm/1.6mm & 2.5mm)

Fig.2: Sprue wax -3.0mm

Fig.3: Surfactant Spray

Fig.4: Phosphate bonded investment material

Fig.5: Colloidal Silica

Fig.6: Distilled water

Fig.7: Low translucency lithium disilicate pressable ingots

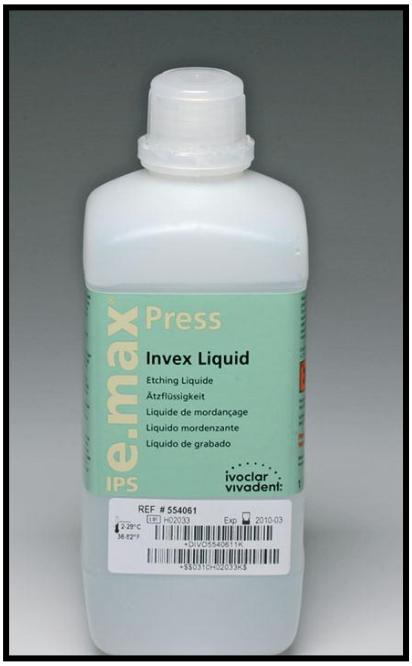


Fig.8: Invex liquid

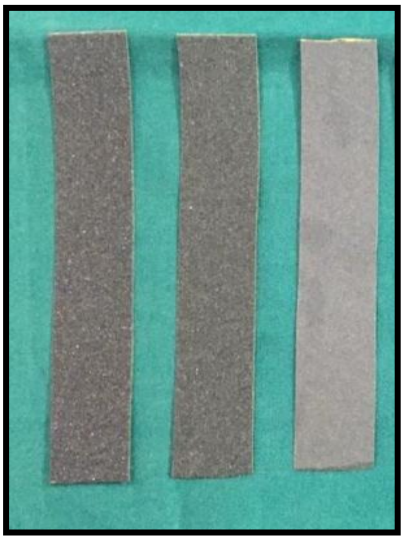


Fig.9:Silicon carbide emery papers

Fig.10: Nickel-Chromium casting alloy pellets

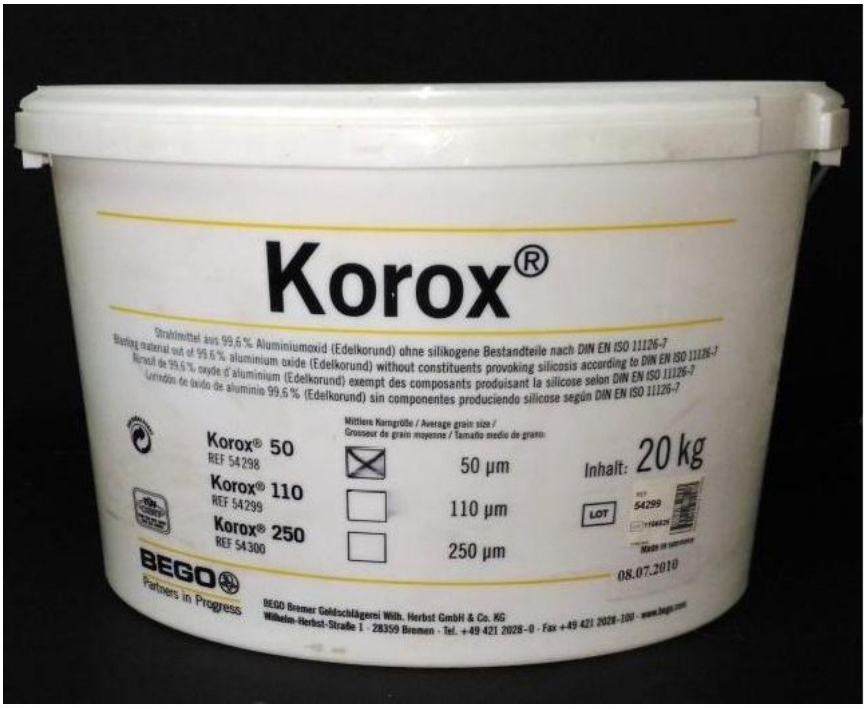


Fig.11: Aluminium oxide -50 µm

Fig.12: White background

Fig.13: Polyvinylsiloxane impression material

Fig.14: Hydrofluoric acid 10%

Fig.15: Brass sheet - 40 μm

Fig.16: Resin Luting cement

INSTRUMENTS

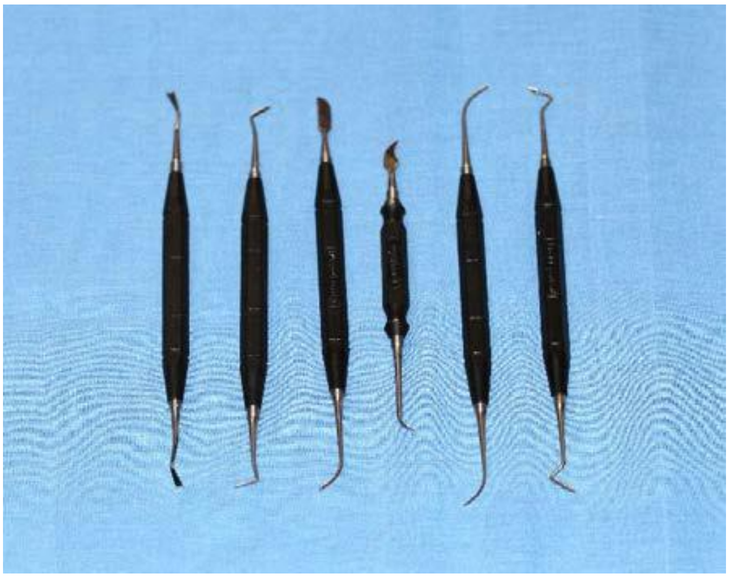


Fig.17: PK Thomas instruments

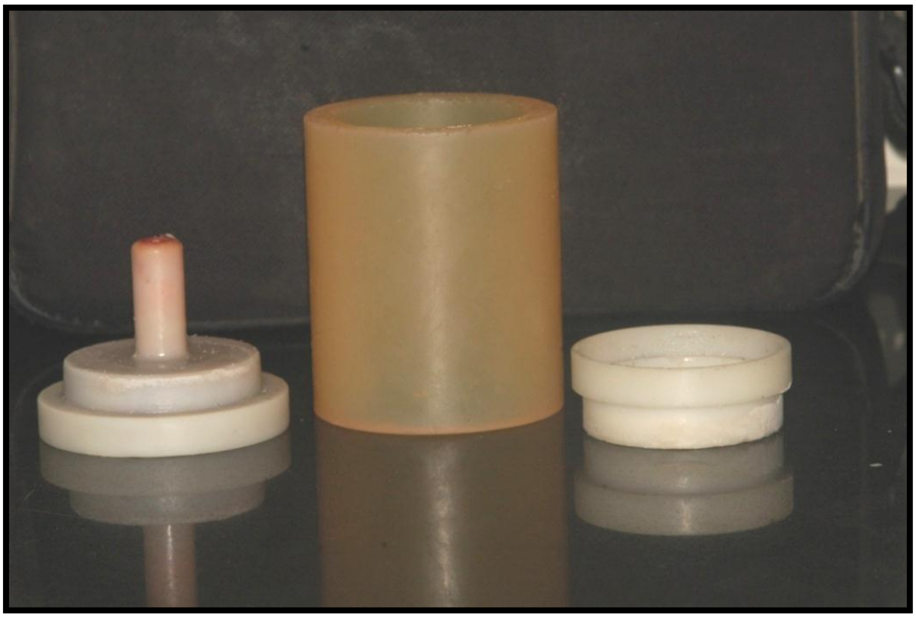


Fig.18: Silicon investment ring system for emax press

Fig.19: Alox plunger

Fig.20: Fine diamond disc

Fig.21: Crucible former and silicone casting ring for metal casting

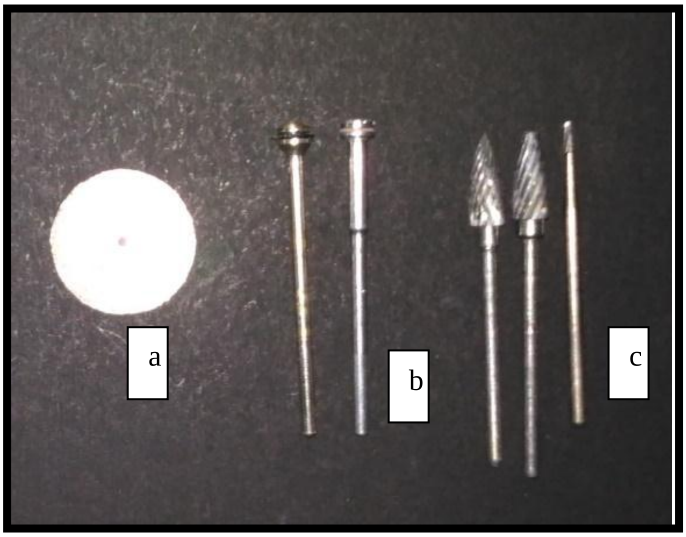


Fig.22: Trimming and finishing kit

a) Metal separating disc

b) Disc mandrel

c) Tungsten carbide burs

Fig.23: Metal rings

Fig.24: a) Scissors b) Probe c) Tweezer

Fig.25: Air tight Dark container

EQUIPMENTS

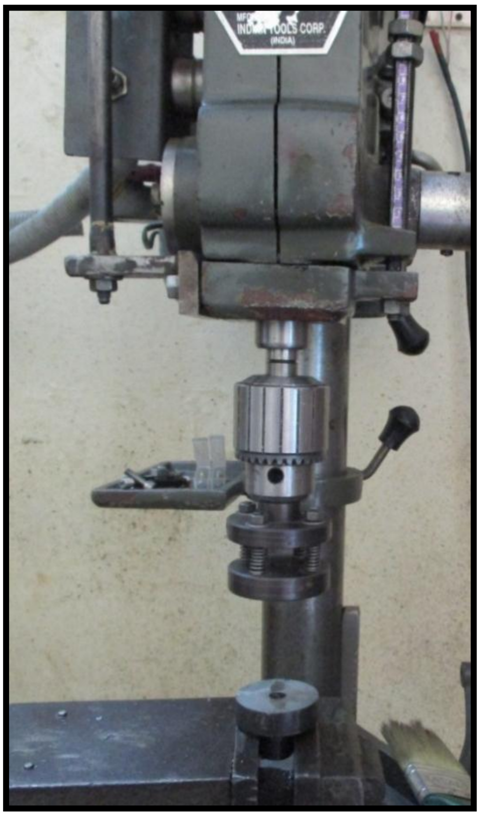


Fig.26: Hand Press machine

Fig.27: Vacuum mixer

Fig.28: Burn out furnace

Fig.29: Heat press furnace

Fig.30: Induction casting machine

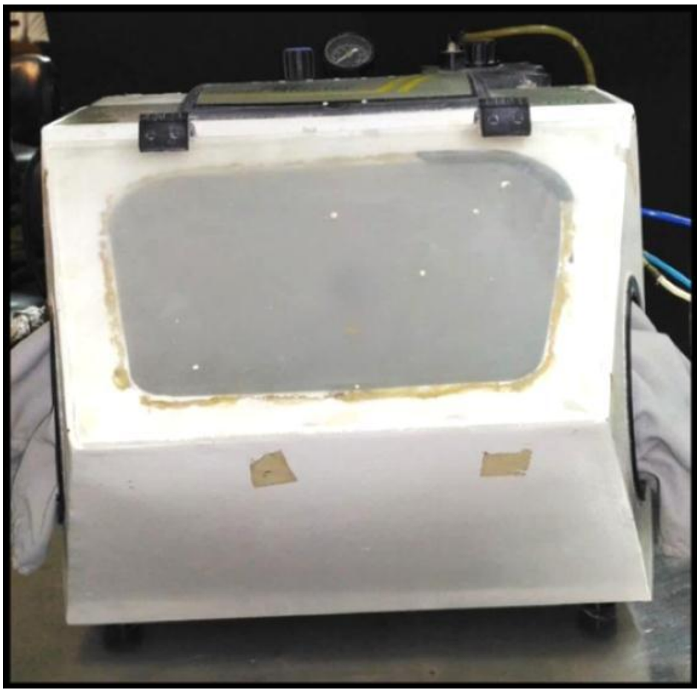


Fig.31: Sandblaster

Fig.32: Alloy grinder

Fig.33: Digital vernier caliper

Fig.34: Digital micrometer

Fig.35: Digital Ultrasonic cleaner

Fig.36: Light curing unit

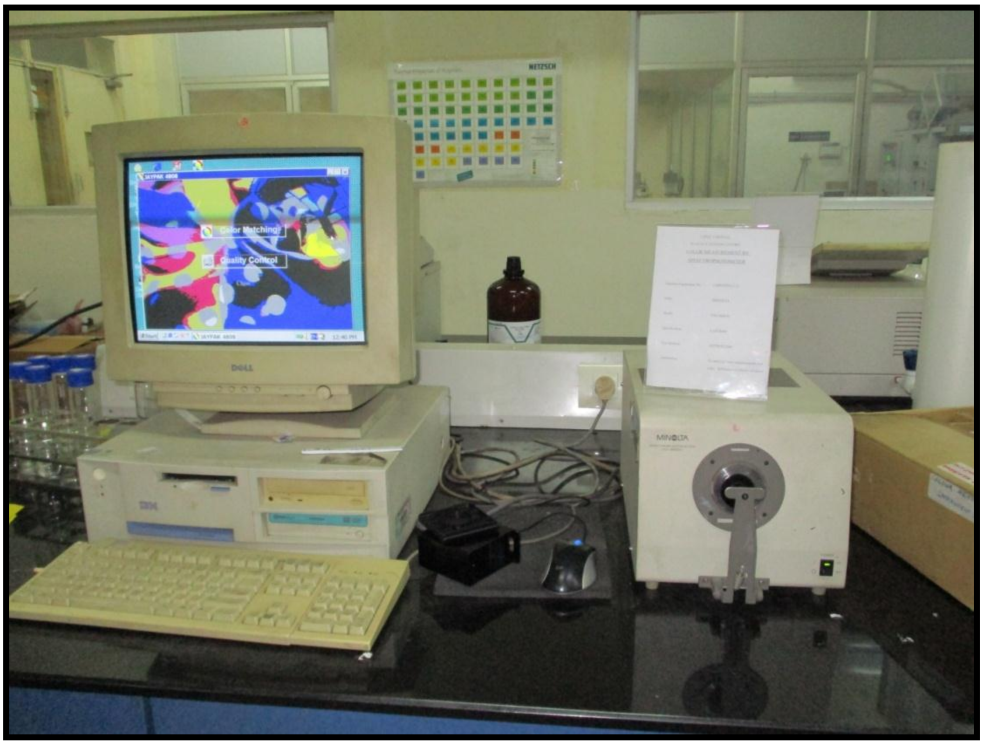


Fig.37: Spectrophotometer

METHODOLOGY

I) Fabrication of custom made metallic mold

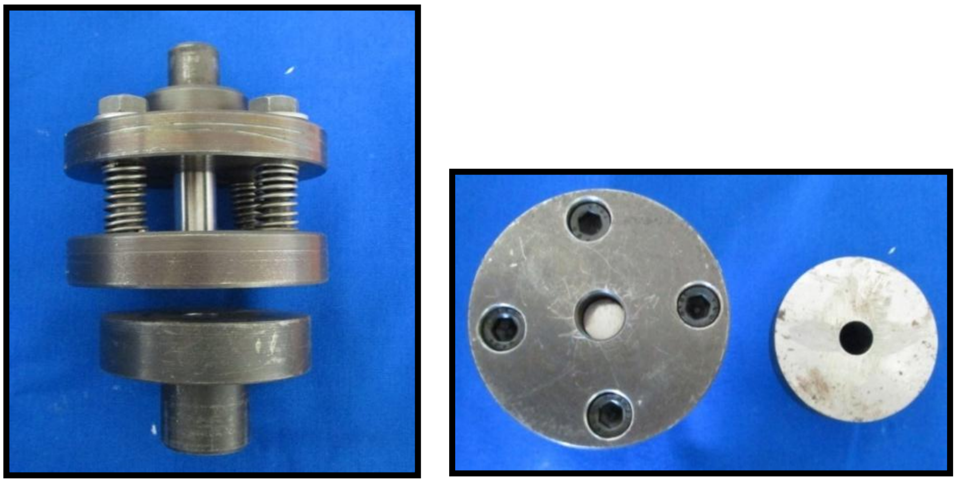


Fig.38: Parts of metallic mold

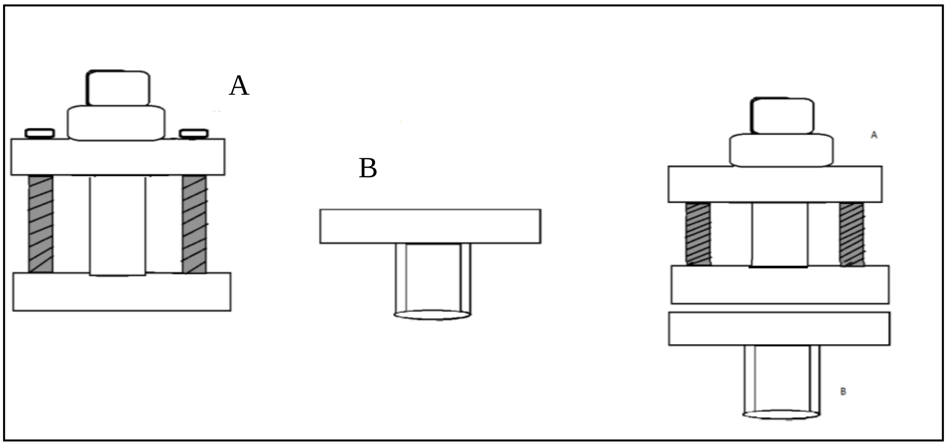


Fig.39: Schematic diagram of metallic mold

A) lower base B) upper counter

II) Fabrication of plastic patterns for lithium disilicate ceramic discs and Ni-Cr metal discs

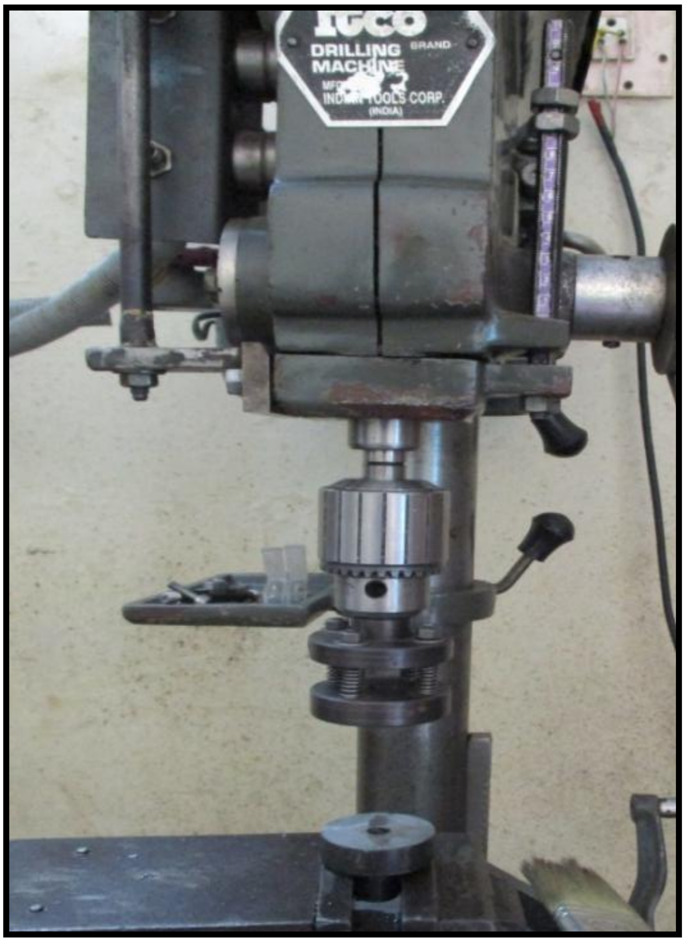


Fig.40:Metallic mold in hand press machine

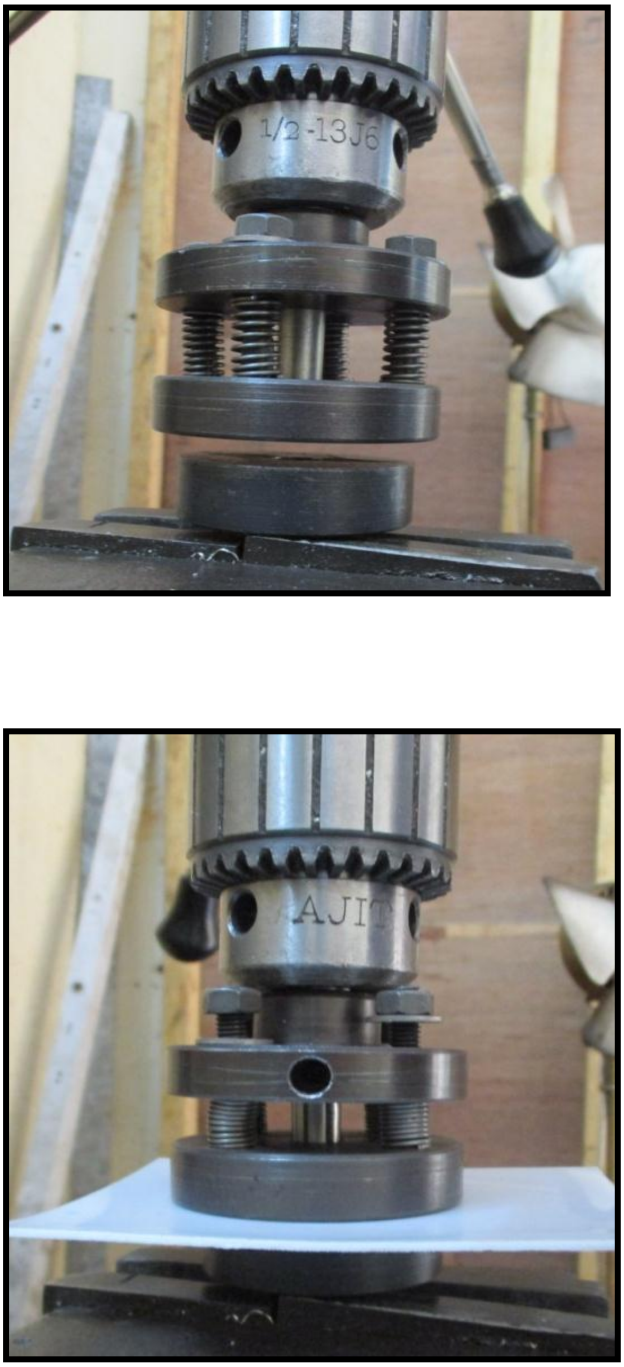


Fig.41: Spring action of metallic mold

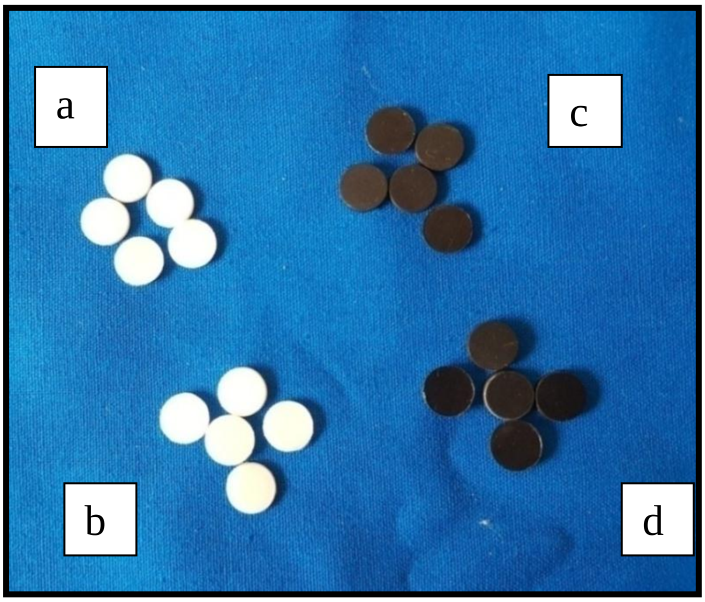


Fig.42: Patters for ceramic disc fabrication: a) 1mm b) 1.3mm c) 1.6mm

Patterns for Ni-Cr metal discs fabrication-: d) 2.5mm

III) Fabrication of Heat pressed ceramic discs

A) Investing of patterns

Fig.43: Verification of diameter of pattern (10mm)

Fig.44: Verification of thickness of pattern (1mm)

Fig.45: Verification of thickness of pattern (1.3 mm)

Fig.46: Verification of thickness of pattern (1.6 mm)

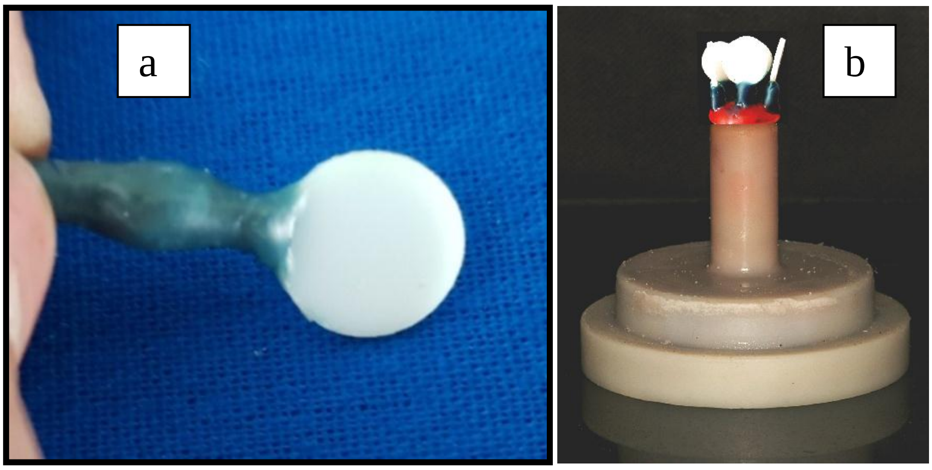


Fig.47a: Spruing of pattern

47b: Attachment of sprued patterns to investment base

Fig.47c: Investing of patterns

Fig.48: Burnout procedure

B) Heat pressing

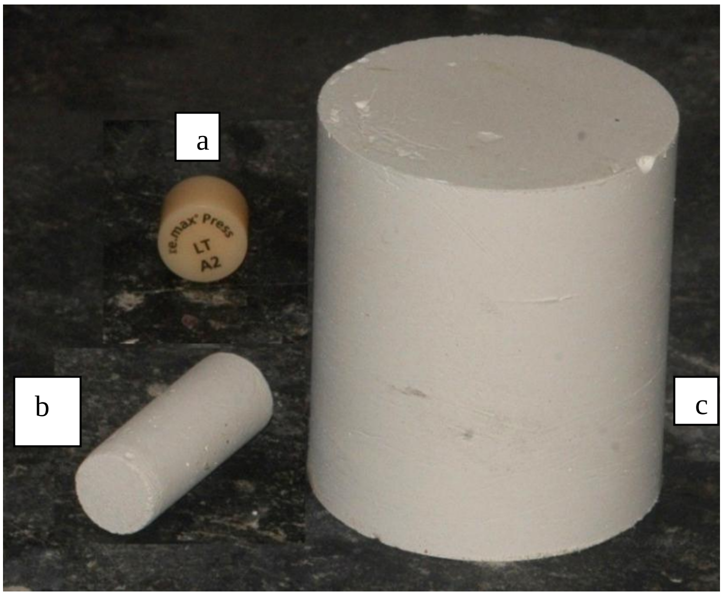


Fig.49: a) Ingot b) Alox plunger c) Investment mold

Fig.50: Placement of LT lithium disilicate ingot with investment tong

Fig.51: Heat pressing of ingot

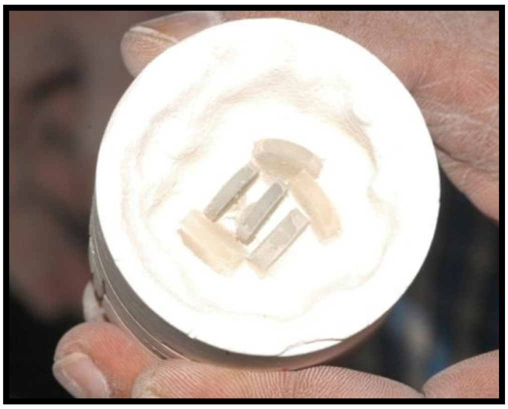


Fig.52a: Heat pressed ceramic discs

Fig.52b: Separating of the sprue with fine diamond disc

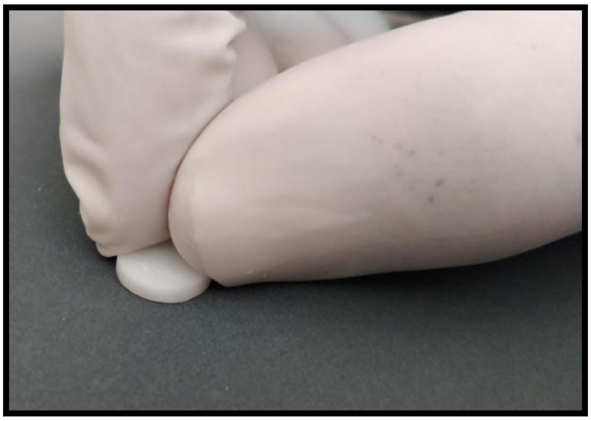


Fig.52 c: Finishing of ceramic disc

IV) Grouping of lithium disilicate ceramic discs:

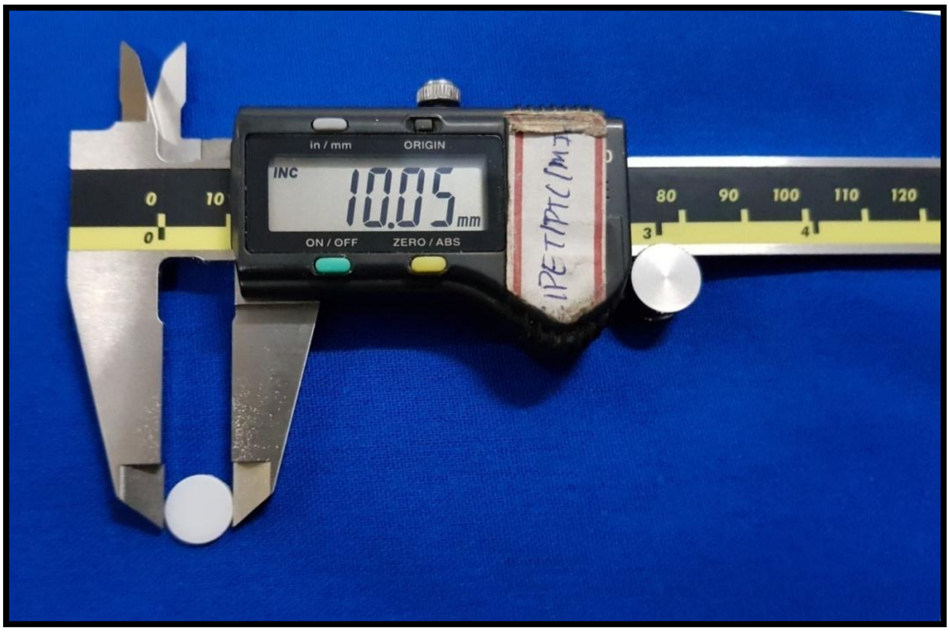


Fig.53: Verification of diameter (10mm)

Fig.54a: Verification of thickness (1mm)

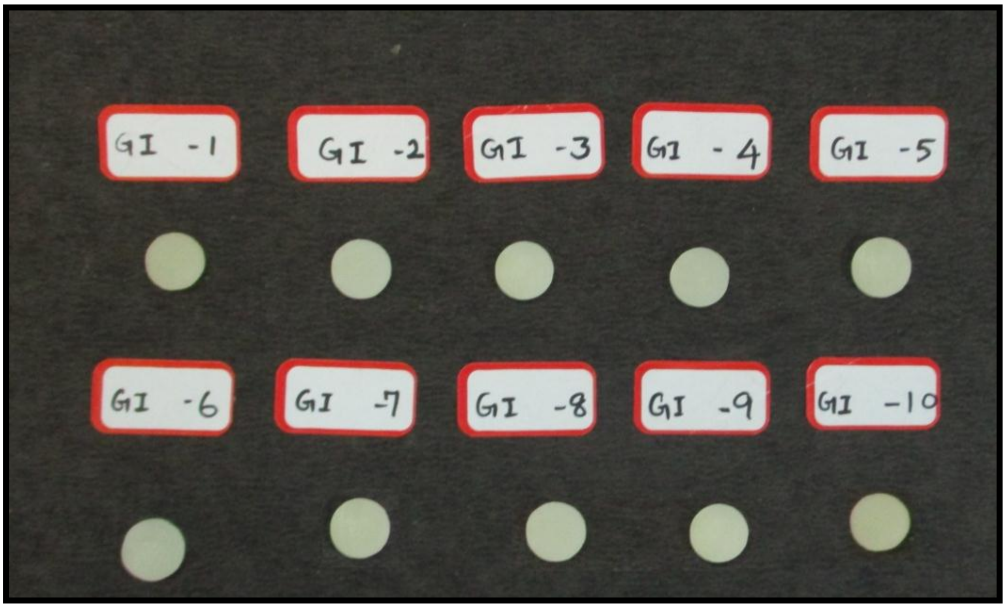


Fig.54b: Grouping of ceramic samples for Group I (1mm)

Fig.55a: Verification of thickness (1.3mm)

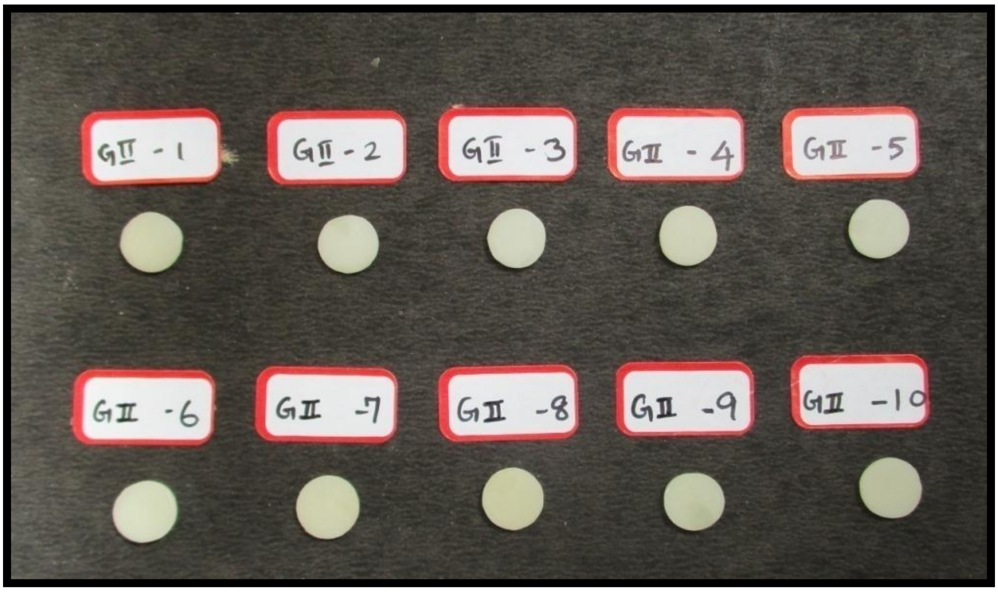


Fig.55b: Grouping of ceramic samples for Group II (1.3mm)

Fig.56a: Verification of thickness (1.6mm)

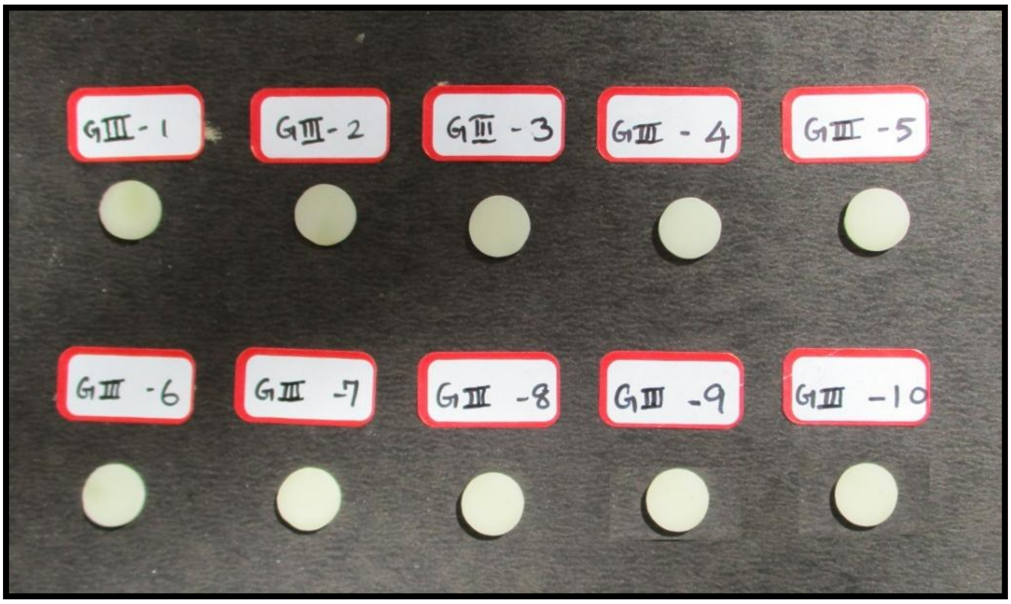


Fig.56b: Grouping of ceramic samples for Group III (1.6mm)

V) Fabrication of Ni-Cr metal discs:

A)Investing and casting of plastic patterns

Fig.57: Verification of pattern for metal disc

Fig.58: Spruing of patterns

Fig.59a: Vacuum mixing of investment material

Fig.59b: Complete Pouring of investment material into silicone ring

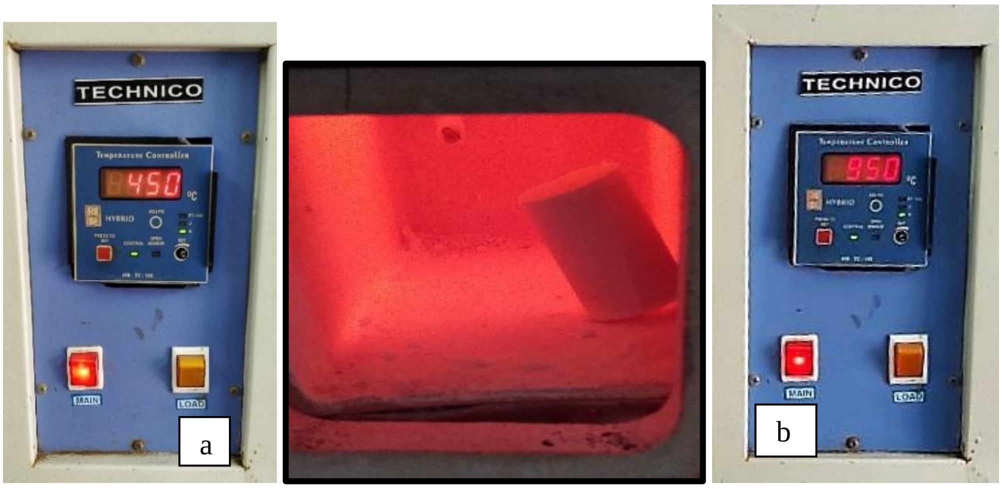


Fig.60 a: Pre-heating temperature   b: Burnout temperature

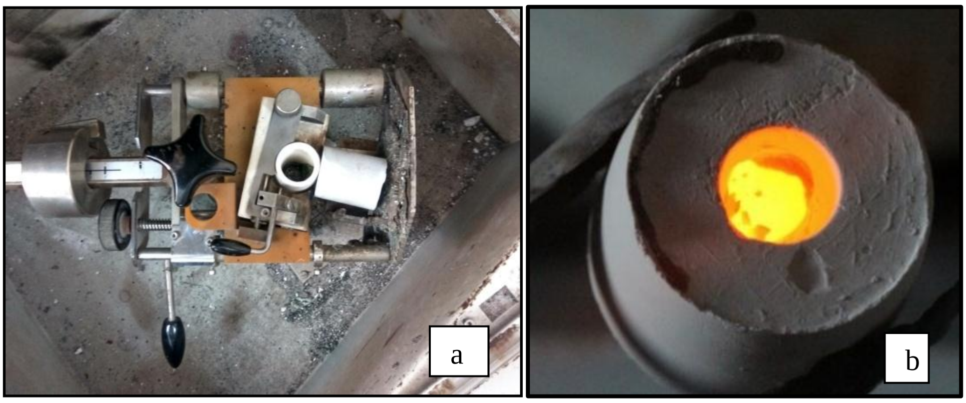


Fig.61: Induction casting procedure

a) Transferring investment mold to casting machine

b) Molten metal in investment mold after casting

B) Finishing and surface treatment of Ni-Cr metal discs by sandblasting

Fig.62a: Divested casting

Fig.62b :Sandblasting

Fig.62c: Separating of the sprue

VI) Grouping of Ni-Cr metal discs

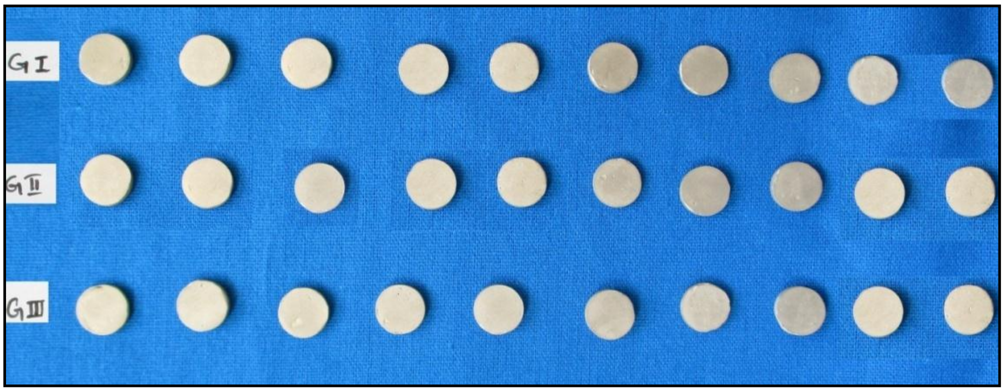


Fig.63: Grouping of Ni-Cr metal discs

VII) Evaluation of colour measurements of Lithium disilicate ceramic discs against white background

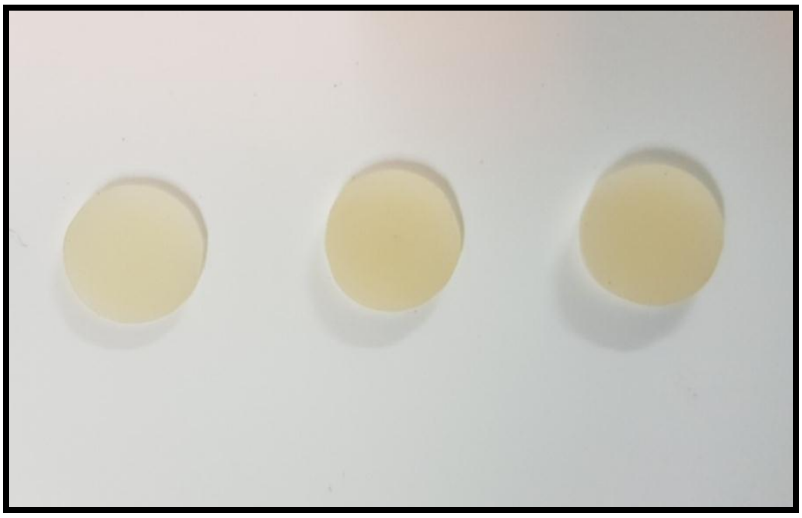


Fig.64a: Evaluation of colour parameters against white background

Fig.64b: Placement of ceramic discs against white background

VIII) Evaluation of colour measurements of Lithium disilicate ceramic discs against Ni-Cr metal discs before cementation.

A) Embedding the metal disc within metal ring

Fig.65a: Embedding metal disc in metal ring using polyvinyl siloxane impression material

Fig.65b: Optical connection of the ceramic disc and Ni-Cr metal disc with distilled water

Fig.66: Colour measurement of ceramic disc against Ni-Cr metal disc

IX) Cementation of Lithium disilicate ceramic discs to Ni-Cr metal discs using resin cement

A) Surface preparation of lithium disilicate discs:

a) Ultrasonic cleaning of discs:

Fig.67: Ultrasonic cleaning of ceramic discs

b) Etching of ceramic:

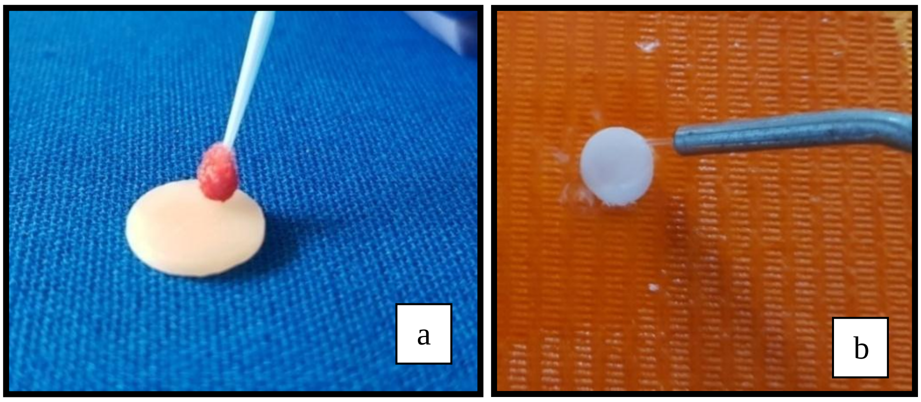
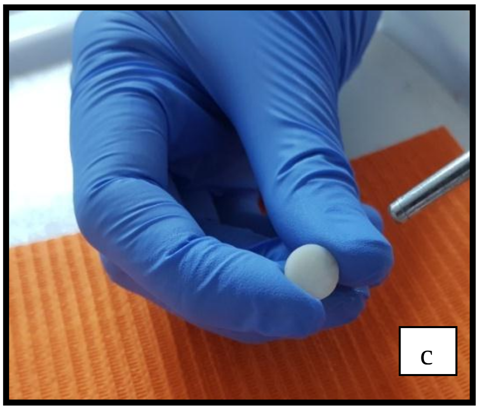


Fig.68a: Application of 10% hydrofluoric acid

Fig.68b: Rinsing with water



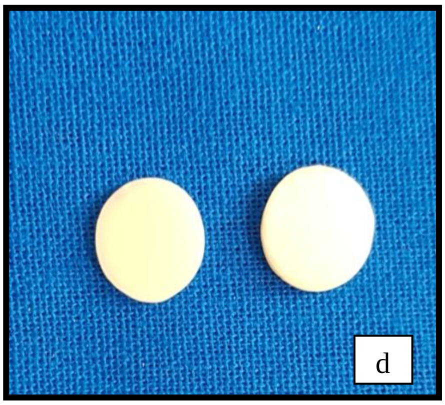


Fig.68c: Air drying

Fig.68d: Non-etched and etched ceramic disc

B) Fabrication of a metallic template to standardize the cement thickness at 40 microns:

Fig.69: Metallic template to maintain cement space

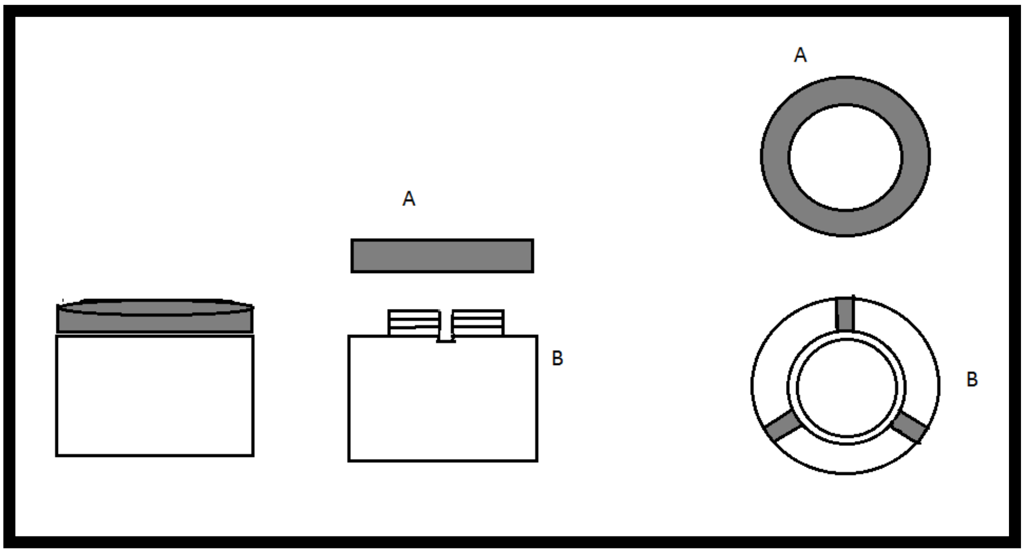


Fig.70: Line diagram of metallic template

C) Cementation of ceramic discs to Ni-Cr metal disc:

Fig.71: Verification of spacer thickness

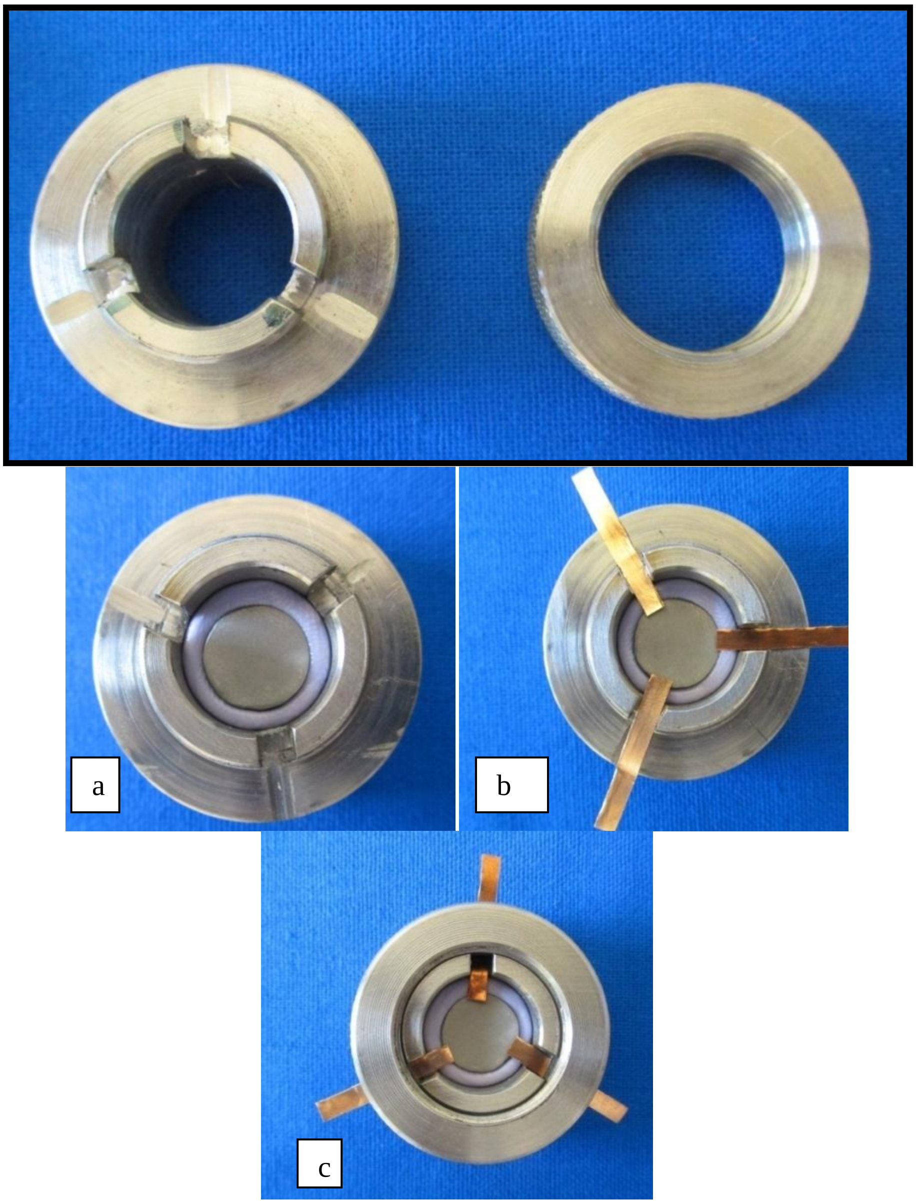


Fig.72a) Embedding metal disc in template with putty

b) Positioning of spacer at the edge of the metal disc

c) Stabilization of the spacer with the upper member of template

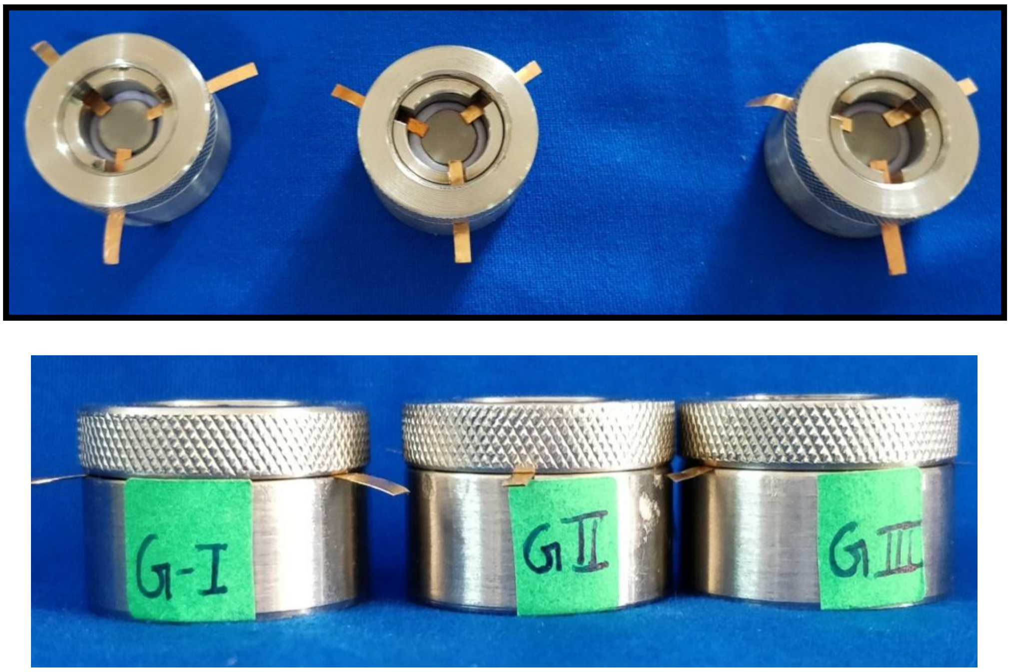


Fig.73: Positioning of 40 µm spacer for all three groups

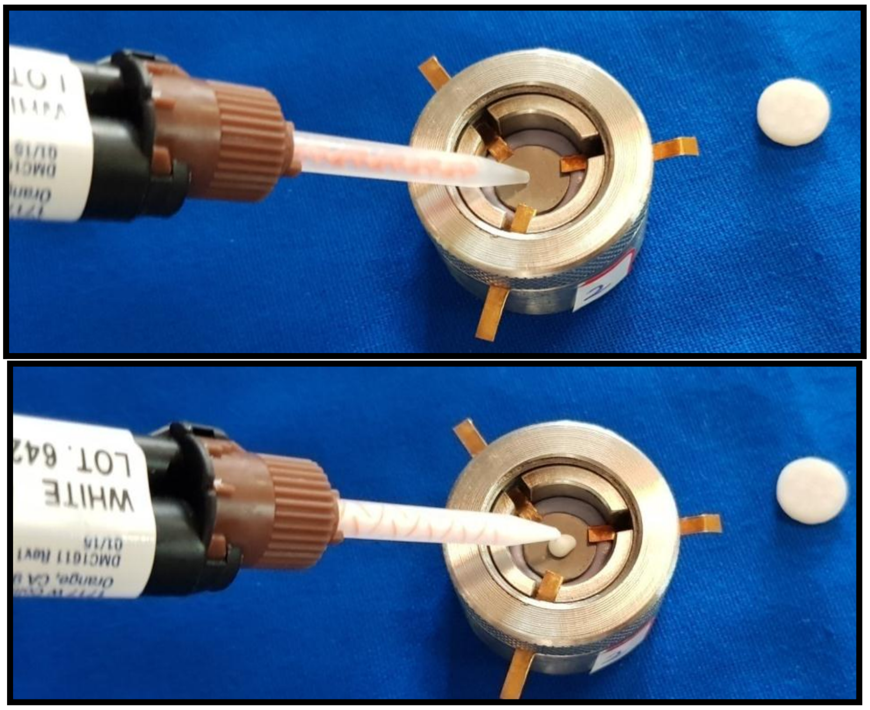
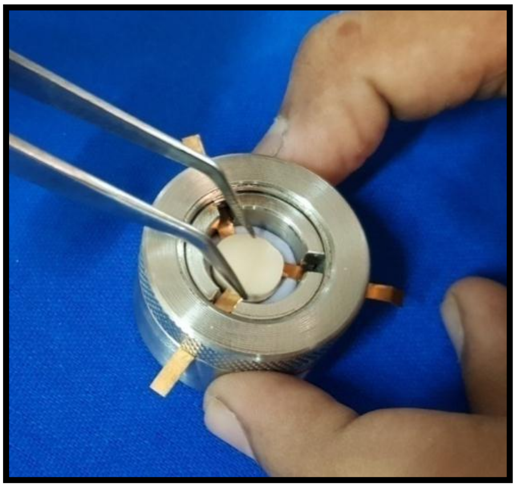


Fig.74a: Dispensing of resin cement



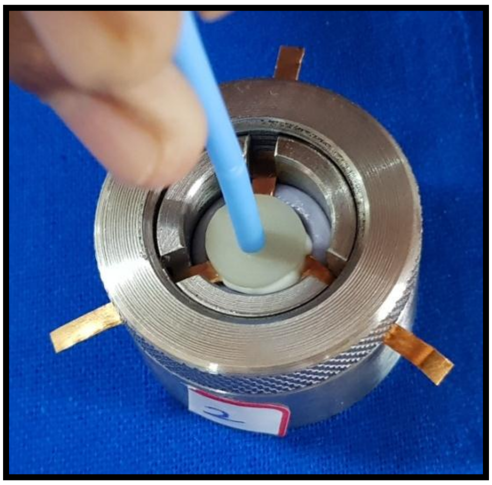


Fig.74b: Placement of ceramic disc

Fig.74c : Pressure applied to remove excess cement

C) Light polymerization

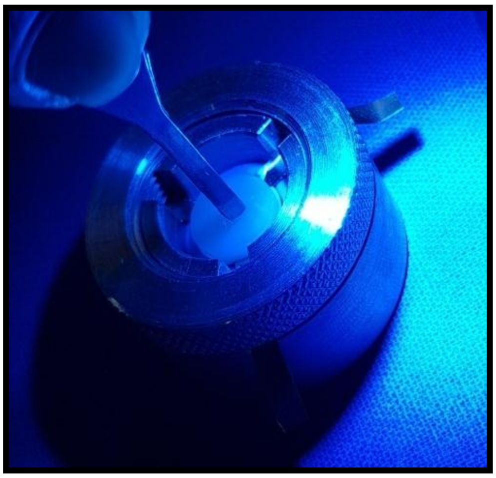


Fig 75.a: Tack curing for 3 sec

Fig.75b: Light polymerization for 40 sec

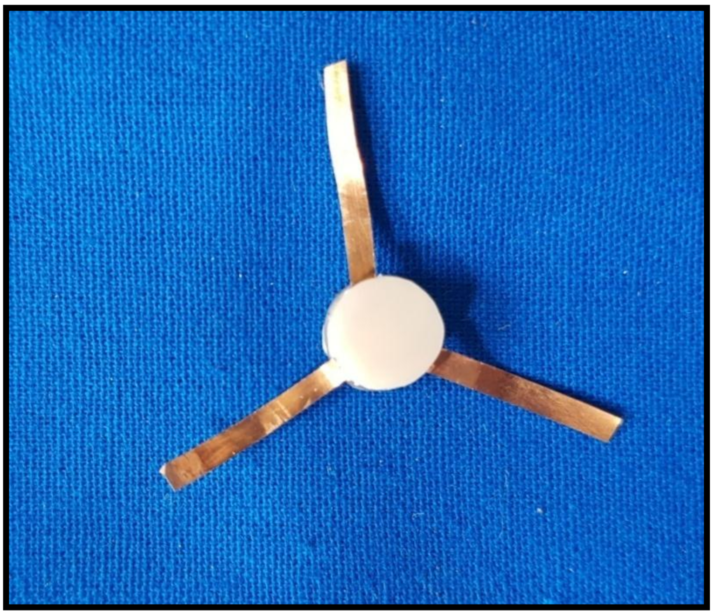


Fig.76: Intact spacer ensuring maintenance of cement space

E) Storage of cemented lithium disilicate ceramic disc-Ni-Cr metal disc in distilled water

Fig.77: Storage of discs in air tight dark container

X) Evaluation of colour measurements of lithium disilicate ceramic discs against Ni-Cr metal discs after cementation

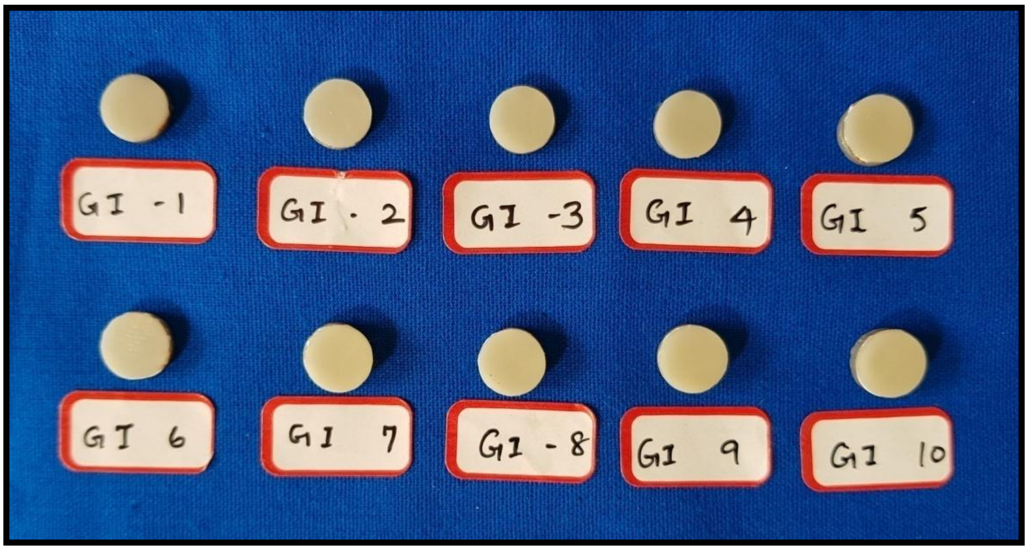


Fig.78: Group I ceramic discs after cementation

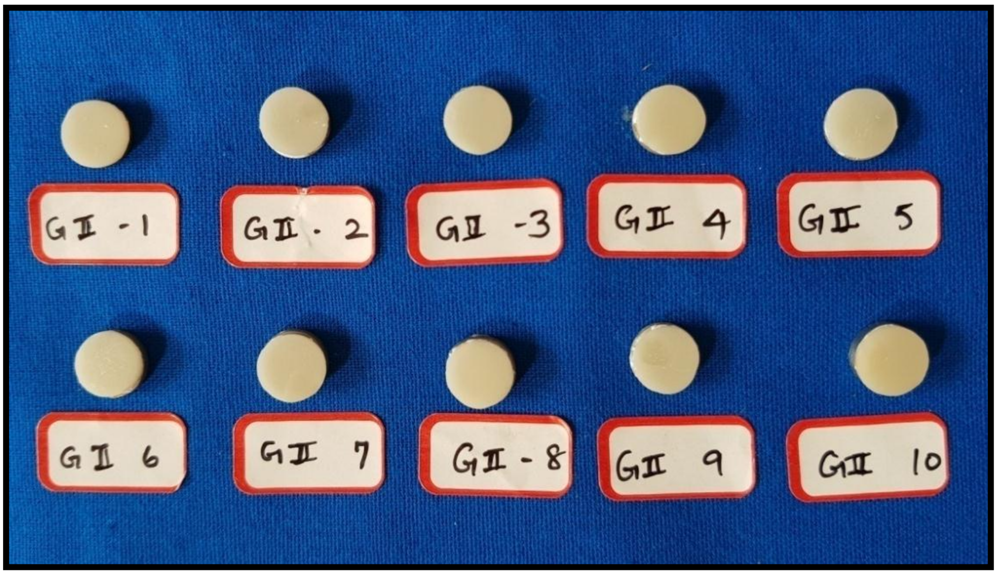


Fig.79: Group II ceramic discs after cementation

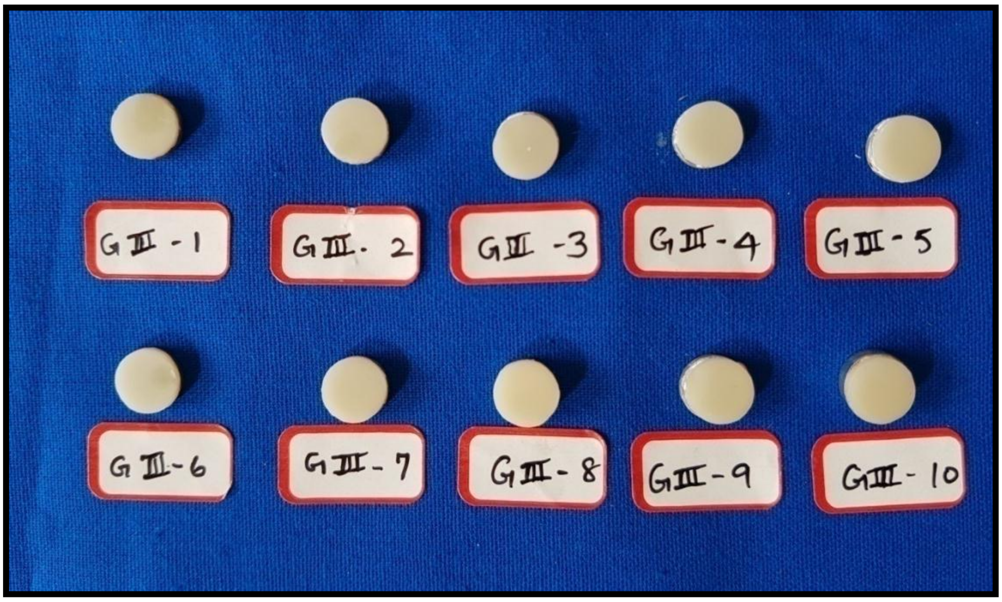


Fig.80: Group III ceramic discs after cementation

Fig.81: Colour measurement following complete polymerization

Results

RESULTS

The present *in vitro* study was conducted to comparatively evaluate the masking ability of Lithium disilicate ceramic with different core thickness on the shade match of indirect restorations over metallic substrate.

A total of 30 heat pressed lithium disilicate ceramic discs of diameter 10mm and thickness of 1mm (Group I), 1.3mm (Group II) and 1.6mm (Group III) were fabricated from low translucency blank. Each group consisted of 10 samples .Similarly thirty Ni-Cr metal discs of uniform diameter of 10mm and thickness of 2.5mm were utilized in the study to serve as metallic substrate and were further divided into 10 metal discs for each group of lithium disilicate ceramic. The $L^*a^*b^*$ parameters were measured with CM-3600d spectrophotometer at wavelength of 360-740 nm. The colour coordinates L*, a*, b* of the ceramic discs before cementation were determined against a white background and the Ni-Cr metal disc. Surface treatment of all the ceramic discs were carried out using 10% hydrofluoric acid for 30 seconds and then they were cemented to the Ni-Cr metal discs with Maxcem Elite resin luting cement. Following complete polymerization, the test samples were subjected to spectrophotometric analysis. The basic data of the colour parameters against the white background, against the Ni-Cr metal discs and following luting of ceramic discs to the metal discs with resin cement are given from Table 1 to Table 9.The colour difference before and after cementation are displayed from Table 10 to Table 16. The results were then statistically analyzed using One-Way ANOVA and paired t-test.

TABLE 1: Basic data of L*a*b* values for Group I Lithium disilicate ceramic discs of thickness 1mm against white background

Sample no	L	a	b
1	76.97	-0.54	9.77
2	76.69	-0.62	8.55
3	77.00	-0.39	9.84
4	77.06	-0.34	10.58
5	77.10	-0.53	9.75
6	77.26	-0.43	9.35
7	76.93	-0.35	8.42
8	76.56	-0.62	8.33
9	76.83	-0.61	8.91
10	77.08	-0.33	10.63
MEAN	**76.95**	**-0.48**	**9.4**

Inference:

1.The maximum 'L' value was **77.26** and the minimum 'L' value was **76.56** and the mean 'L' value was **76.95** against white background.

2.The maximum 'a' value was **-0.33** and the minimum 'a' value was **-0.62** and the mean 'a' value was **-0.48** against white background.

3.The maximum 'b' value was **10.63** and the minimum 'b' value was **8.33** and the mean 'b' value was **9.4** against white background.

TABLE 2: Basic data of L*a*b* values for Group II Lithium disilicate ceramic discs of thickness 1.3 mm against white background

Sample no	**L**	**a**	**b**
1	74.81	0.19	11.51
2	74.26	0.16	11.29
3	74.88	-0.52	9.35
4	74.31	0.22	11.81
5	74.60	-0.33	10.06
6	74.50	0.22	11.60
7	74.6	-0.32	10.12
8	74.05	0.72	11.99
9	73.86	0.23	11.63
10	74.97	-0.54	9.18
Mean	**74.48**	**0.003**	**10.85**

Inference:

1.The maximum ‘L’ value was **74.97** and the minimum ‘L’ value was **73.86** and the mean ‘L’ value was **74.48** against white background.

2. The maximum ‘a’ value was **0.72** and the minimum ‘a’ value was **- 0.54** and the mean ‘a’ value was **0.003** against white background.

3. The maximum ‘b’ value was **11.99** and the minimum ‘b’ value was**9.18** and the mean ‘b’ value was **10.85** against white background.

TABLE 3: Basic data of L*a*b* values for Group III Lithium disilicate ceramic discs of thickness 1.6mm against white background

Sample no	L	a	b
1	70.51	0.50	12.86
2	72.11	0.40	10.96
3	73.27	-0.29	10.64
4	73.53	-0.33	10.58
5	73.23	0.33	12.53
6	72.59	-0.35	10.90
7	73.13	0.31	12.43
8	73.74	-0.32	10.57
9	71.56	0.40	11.19
10	70.73	-0.48	12.40
Mean	**72.44**	**0.017**	**11.50**

Inference:

1).The maximum 'L' value was **73.74** and the minimum 'L' value was **70.51** and the mean 'L' value was **72.44** against white background.

2).The maximum 'a' value was **0.50** and the minimum 'a' value was **-0.48 a**nd the mean 'a' value was = **0.017** against white background.

3).The maximum 'b' value was **12.86** and the minimum 'b' value was **10.57** and the mean 'b' value was **11.50** against white background.

TABLE 4: Basic data of L*a*b* values for Group I Lithium disilicate ceramic discs of thickness 1mm against Ni-Cr metal discs before cementation

Sample no	L	a	b
1	60.70	-1.26	2.16
2	61.12	-1.24	1.68
3	61.52	-1.28	2.08
4	61.93	-1.27	2.60
5	60.88	-1.23	2.02
6	61.56	-1.28	1.83
7	60.37	-1.30	2.30
8	61.38	-1.23	1.73
9	60.87	-1.25	1.63
10	62.24	-1.26	2.67
Mean	**61.26**	**-1.26**	**2.07**

Inference:

1) The maximum 'L' value was **62.24** and the minimum 'L' value was **60.37** and the mean 'L' value was **61.26** against **Ni-Cr metal discs.**

2) The maximum 'a' value was **-1.23** and the minimum 'a' value was **-1.30** and the mean 'a' value was **-1.26** against **Ni-Cr metal discs.**

3) The maximum 'b' value was **2.67** and the minimum 'b' value was**1.63** and the mean 'b' value was **2.07** against **Ni-Cr metal disc.**

TABLE 5: Basic data of L*a*b* values for Group II Lithium disilicate ceramic discs of thickness 1.3mm against Ni-Cr metal discs before cementation

Sample no	L	a	b
1	63.54	-1.11	4.65
2	63.51	-1.11	4.64
3	63.22	-1.39	2.56
4	63.77	-1.25	4.10
5	64.80	-1.37	2.44
6	64.94	-1.06	4.40
7	64.00	-1.37	2.67
8	63.63	-0.57	1.87
9	63.78	-1.26	4.08
10	62.88	-1.39	2.58
Mean	**63.80**	**-1.19**	**3.40**

Inference:

1) The maximum 'L' value was **64.94** and the minimum 'L' value was **62.88** and the mean value 'L' was **63.80** against **Ni-Cr metal discs.**

2).The maximum 'a' value was **-0.57** and the minimum 'a' value was **-1.39** and the mean 'a' value was **-1.19** against **Ni-Cr metal discs.**

3).The maximum 'b' value was **4.65** and the minimum 'b' value was **2.44** and the mean 'b' value was **3.40** against **Ni-Cr metal discs.**

TABLE 6: Basic data of L*a*b* values for Group III Lithium disilicate ceramic discs of thickness 1.6mm against Ni-Cr metal discs before cementation

Sample no	L	a	b
1	61.89	-1.65	3.05
2	63.46	-1.65	3.75
3	65.30	-1.38	3.65
4	64.47	-1.39	3.62
5	64.75	-1.25	4.71
6	63.80	-1.07	2.62
7	64.72	-1.26	4.26
8	64.86	-1.34	3.58
9	63.31	-1.69	3.73
10	61.38	-1.95	3.88
Mean	**63.79**	**-1.46**	**3.68**

Inference:

1)The maximum 'L' value was **65.30** and the minimum 'L' value was **61.38** and the mean 'L' value was **63.79** against **Ni-Cr metal discs.**

2) The maximum 'a' value was **-1.07** and the minimum 'a' value was **-1.95** .and the mean 'a' value was **-1.46** against **Ni-Cr metal discs.**

3) The maximum 'b' value was **4.71** and the minimum 'b' value was **2.62** and the mean 'b' value was **3.68** against **Ni-Cr metal discs.**

TABLE 7: Basic data of L*a*b* values for Group I Lithium disilicate ceramic discs of thickness 1 mm after cementation with Ni-Cr metal discs

Sample no	L	a	b
1	60.60	-1.01	2.43
2	62.65	-1.50	1.62
3	62.27	-1.44	2.30
4	63.33	-1.29	3.04
5	60.81	-1.28	2.51
6	62.24	-1.41	2.28
7	60.92	-1.00	2.58
8	62.79	-1.49	1.63
9	63.10	-1.41	1.77
10	63.98	-1.05	3.39
Mean	**62.27**	**-1.29**	**2.35**

Inference:

1)The maximum 'L' value was **63.98** and the minimum'L' value was **60.60** and the mean 'L' value was **62.27 after cementation** with Ni-Cr metal discs.

2) The maximum 'a' value was **-1.00** and the minimum 'a' value was **-1.50** and the mean 'a' value was **-1.29 after cementation** with Ni-Cr metal discs.

3) The maximum 'b' value was **3.39** and the minimum 'b' value was **1.62** and the mean'b' value was **2.35 after cementation** with Ni-Cr metal disc.

TABLE 8: Basic data of L*a*b* values for Group II Lithium disilicate discs of thickness 1.3mm after cementation with Ni-Cr metal discs

Sample no	L	a	b
1	64.20	-1.25	4.97
2	64.07	-1.29	4.92
3	63.69	-1.43	2.95
4	64.07	-1.27	4.70
5	67.83	-1.66	1.77
6	65.20	-1.30	4.64
7	67.29	-1.66	1.88
8	63.59	-1.02	4.52
9	63.99	-1.29	4.78
10	63.26	-1.58	2.64
Mean	**64.72**	**-1.38**	**3.77**

Inference:

1)The maximum L value was **67.83** and the minimum' L' value was **63.26** and the mean 'L' value was **64.72 after cementation** with Ni-Cr metal discs.

2).The maximum 'a' value was **-1.02** and the minimum 'a' value was **- 1.66** and the mean 'a' value was **-1.38 after cementation** with Ni-Cr metal discs.

3).The maximum 'b' value was **4.97** and the minimum 'b' value was **1.77** and the mean 'b' value was **3.77 after cementation** with Ni-Cr metal discs.

TABLE 9: Basic data of L*a*b* values for Group III Lithium disilicate discs of thickness 1.6mm after cementation with Ni-Cr metal discs

Sample no	L	a	b
1	62.56	-2.15	4.90
2	63.90	-1.78	3.68
3	65.09	-1.54	4.09
4	65.02	-1.54	3.86
5	65.80	-1.13	5.43
6	63.50	-1.75	3.80
7	65.72	-1.04	5.19
8	64.73	-1.56	3.84
9	63.75	-1.79	3.37
10	61.53	-2.51	5.58
Mean	**64.16**	**-1.68**	**4.37**

Inference:

1)The maximum 'L' value was **65.72** and the minimum 'L' value was **61.53** and the mean 'L' value was **64.16 after cementation** with Ni-Cr metal discs**.**

2).The maximum 'a' value was **-1.04** and the minimum 'a' value was **-2.51** and the mean 'a' value was **-1.68 after cementation** with Ni-Cr metal discs.

3).The maximum 'b' value was **5.58** and the minimum 'b' value was **3.37** and the mean 'b' value was **4.37 after cementation** with Ni-Cr metal discs.

TABLE 10:Comparative evaluation of colour difference (ΔE) between Group I (1mm),Group II (1.3mm) and Group III (1.6 mm) ceramic discs against white background and Ni-Cr metal discs before cementation

Sample no	Group I ΔE	Group II ΔE	Group III ΔE
1	17.80	13.15	13.22
2	17.00	12.70	11.31
3	17.33	13.37	10.60
4	17.11	13.14	11.44
5	17.90	12.45	11.60
6	17.40	12.03	12.08
7	17.68	13.00	11.80
8	16.50	14.50	11.34
9	17.55	12.66	11.19
10	16.90	13.14	12.70
MEAN	**17.32**	**13.01**	**11.73**

Inference:

1)The maximum ΔE was **17.90** and minimum ΔE was **16.50** and mean ΔE value was **17.32** for Group I before cementation against **Ni-Cr metal discs.**

2) The maximum ΔE was **14.50** and minimum ΔE was **12.03** and the mean ΔE value was **13.01** for Group II before cementation against **Ni-Cr metal discs.**

3) The maximum ΔE was **13.22** and minimum ΔE was **10.60** and the mean ΔE value was **11.73** for Group III before cementation against **Ni-Cr metal discs.**

TABLE 11: Comparative evaluation of colour difference (ΔE) between Group I (1mm), Group II (1.3mm) and Group III (1.6 mm) ceramic discs against white background and Ni-Cr metal discs after cementation

Sample no	Group I ΔE	Group II ΔE	Group III ΔE
1	17.94	12.50	11.55
2	15.68	12.10	11.05
3	16.60	12.90	10.50
4	15.66	12.55	10.90
5	17.84	10.70	10.30
6	16.62	11.70	11.61
7	17.05	11.09	10.44
8	15.45	12.96	11.31
9	15.49	12.13	11.26
10	14.90	12.40	11.60
MEAN	**16.32**	**12.10**	**11.05**

Inference:

1) The maximum ΔE was **17.94** and minimum ΔE was **14.90** and the mean ΔE value was **16.32** for Group I after cementation with **Ni-Cr metal discs.**

2)The maximum ΔE was **12.96** and minimum ΔE was **10.70** and the mean ΔE value was **12.10** for Group II after cementation with **Ni-Cr metal discs.**

3) The maximum ΔE was **11.61** and minimum ΔE was **10.30** and the mean ΔE value was **11.05** for Group III after cementation with **Ni-Cr metal discs.**

TABLE 12: Overall comparison of the mean colour difference (ΔE) between Group I (1mm), Group II (1.3mm) and Group III (1.6 mm) ceramic discs before cementation using One-Way ANOVA analysis

Group	Mean ΔE	Standard Deviation	p value
I	17.32	0.441	<0.001*
II	13.01	0.658	
III	11.73	0.766	

*p<0.05, statistically significant

Inference: The mean colour difference before cementation showed statistically significant difference among the three groups (p <0.05).

TABLE 13: Multiple comparison of the mean colour difference (ΔE) between Group I, Group II and Group III before cementation using Post hoc Tukey HSD analysis

	Groups	Mean ΔE	p value
Before cementation	I & II	17.32/13.01	0.000*
	I &III	17.32/11.73	0.000*
	II &III	13.01/11.73	0.000*

*p<0.05, statistically significant

Inference:

On multiple comparison of the mean colour difference (ΔE) before cementation, Group II exhibited significantly lesser ΔE value than Group I. However, Group III exhibited significantly lowest ΔE value compared to Group I and Group II.

TABLE 14: Overall Comparison of the mean colour difference (ΔE) between Group I (1mm), Group II (1.3mm) and Group III (1.6 mm) ceramic discs after cementation using One Way ANOVA analysis

Group	Mean ΔE	Standard Deviation	p value
I	16.32	1.051	<0.001*
II	12.10	0.743	
III	11.05	0.499	

*p<0.05, statistically significant

Inference: The mean colour difference after cementation showed statistically significant difference among the three groups (p <0.05).

TABLE 15: Multiple comparison of the mean colour difference (ΔE) between Group I, Group II and Group III after cementation using Post hoc Tukey HSD analysis

	Groups	Mean ΔE	p value
After cementation	I & II	16.32/12.10	0.000*
	I &III	16.32/11.05	0.000*
	II &III	12.10/11.05	0.000*

*p<0.05, statistically significant

Inference:

On multiple comparison of the mean colour difference (ΔE) after cementation, Group II exhibited significantly lesser ΔE than Group I. However, Group III exhibited significantly lowest ΔE value compared to Group I and Group II.

TABLE 16: Comparison of the mean colour difference (ΔE) of before and after cementation for Group I (1mm), Group II (1.3mm) and Group III (1.6 mm) using paired 't' test

GROUP		Mean colour difference (ΔE)	Std. Deviation	p value
I	Before	17.32	0.441	0.002*
	After	16.32	1.051	
II	Before	13.01	0.658	0.001*
	After	12.10	0.743	
III	Before	11.73	0.766	0.008*
	After	11.05	0.499	

*p<0.05, statistically significant

Inference:

The mean colour difference **(ΔE)** of Group I after cementation was found to be significantly lesser than before cementation.

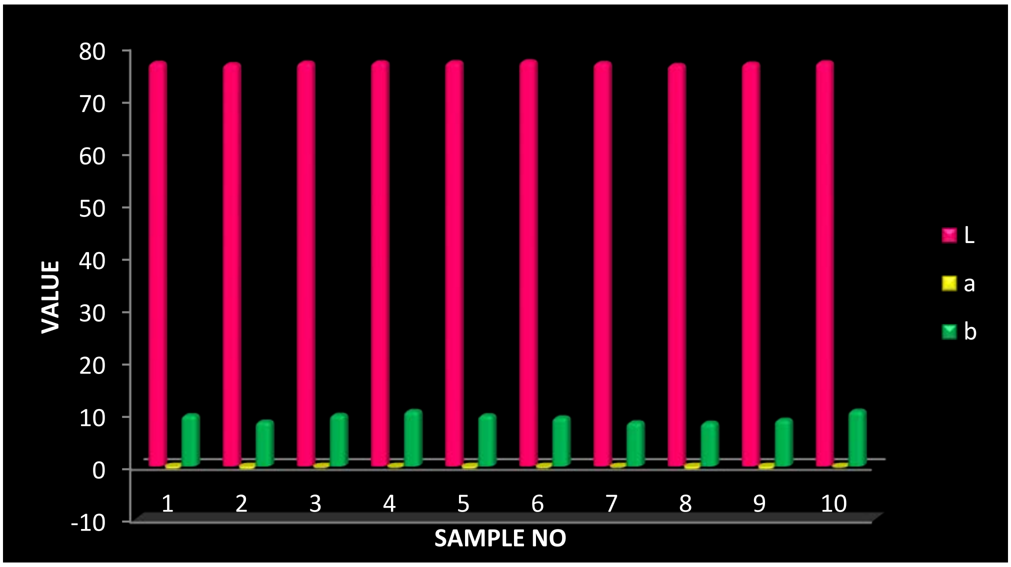
The mean colour difference **(ΔE)** of Group II after cementation was found to be significantly lesser than before cementation.

The mean colour difference **(ΔE)** of Group III after cementation was found to be significantly lesser than before cementation.

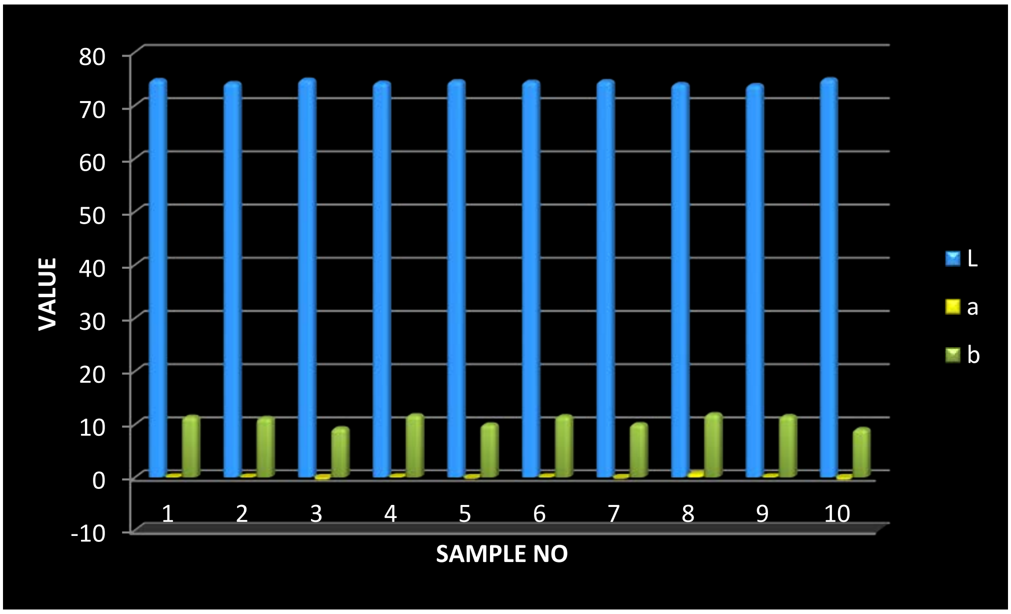
Group III exhibited significantly lowest ΔE value before and after cementation compared to Group I and Group II.

ANNEXURE III

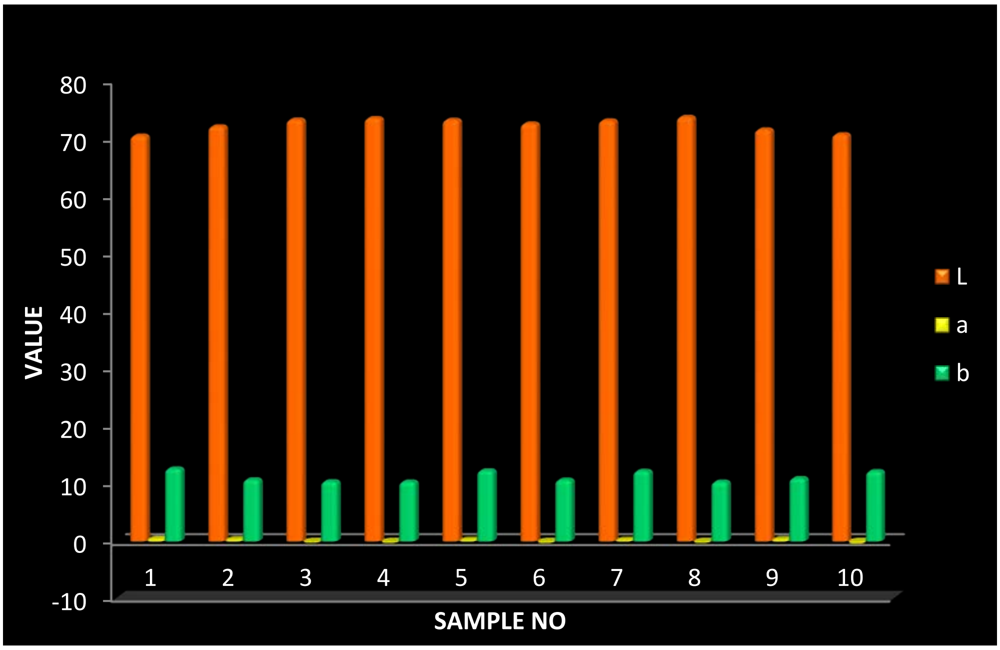
Graph 1: Basic data of L*a*b* values for Group I Lithium disilicate ceramic discs of thickness 1mm against white background



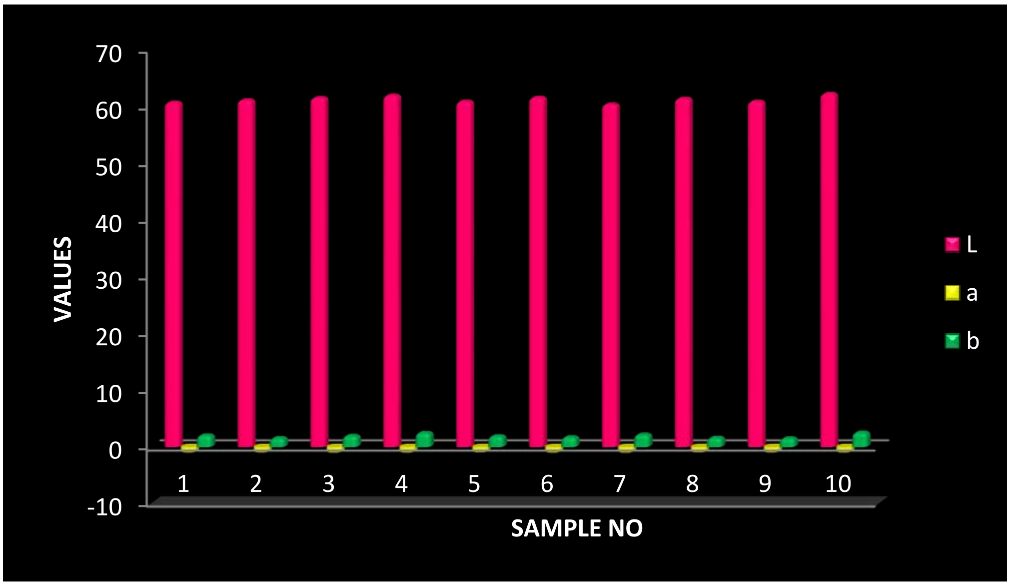
Graph 2: Basic data of L*a*b* values for Group II Lithium disilicate ceramic discs of thickness 1.3 mm against white background



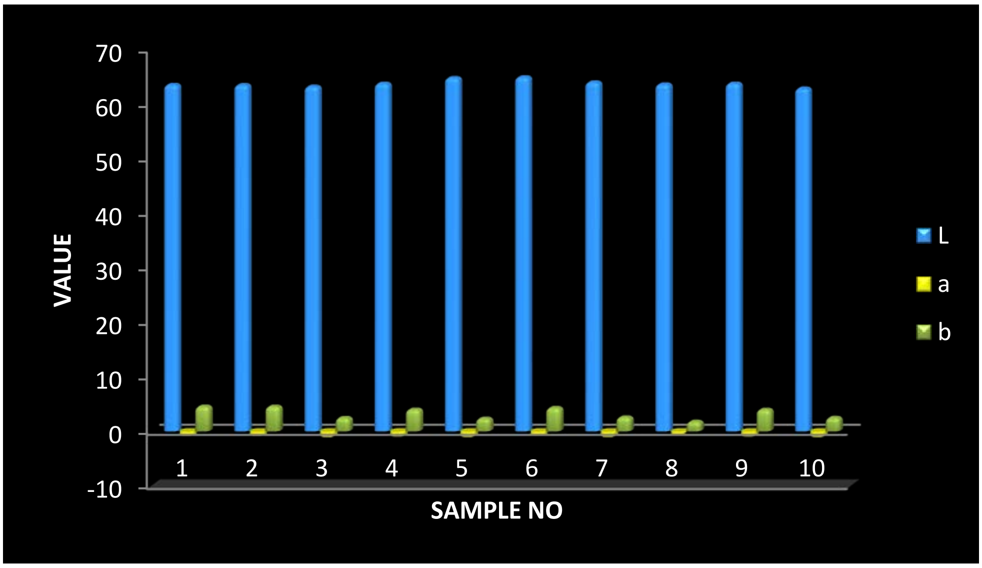
Graph 3: Basic data of L*a*b* values for Group III Lithium disilicate ceramic discs of thickness 1.6 mm against white background



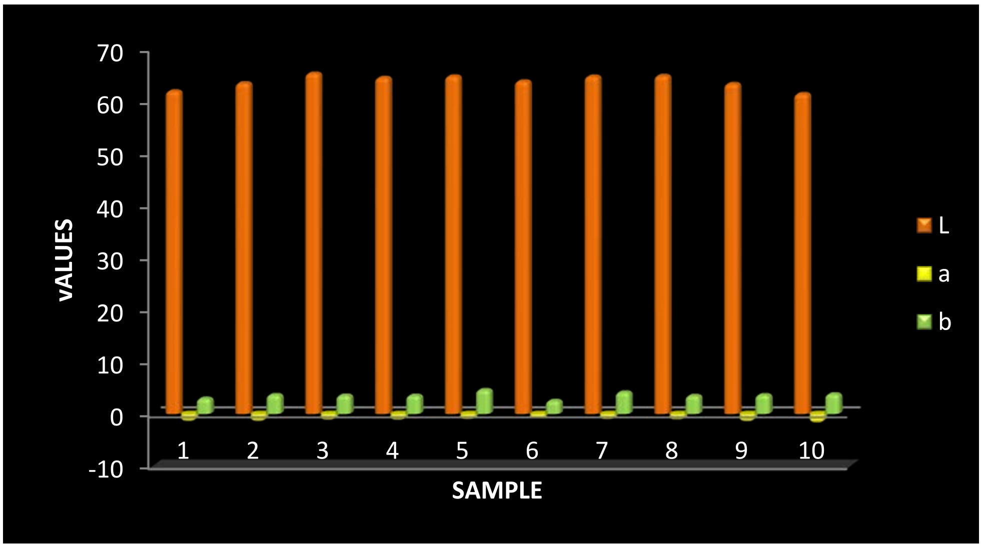
Graph 4: Basic data of L*a*b* values for Group I Lithium disilicate ceramic discs of thickness 1mm against Ni-Cr metal discs before cementation



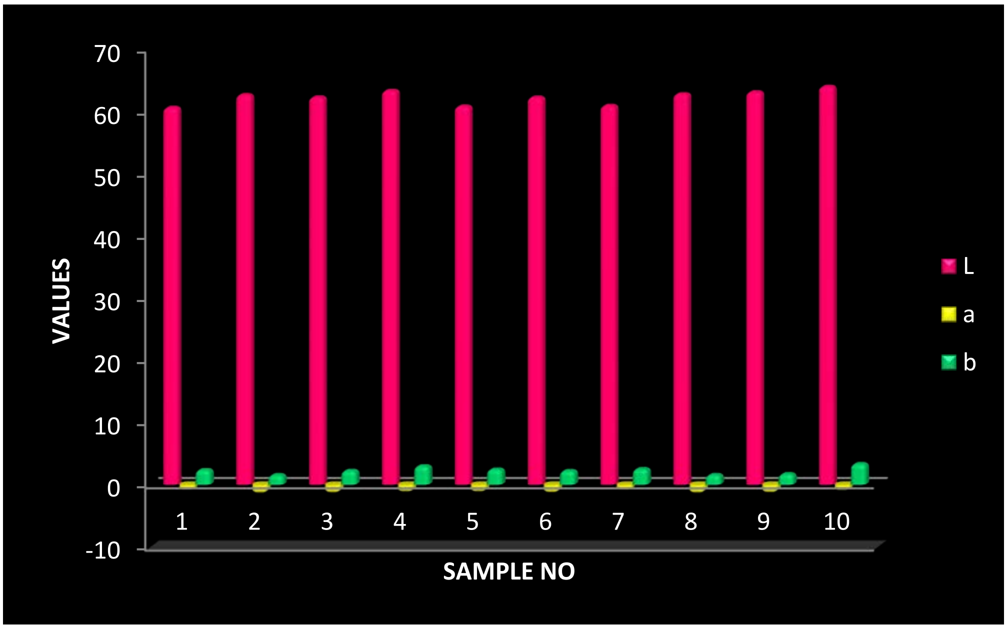
Graph 5: Basic data of L*a*b* values for Group II Lithium disilicate ceramic discs of thickness 1.3mm against Ni-Cr metal discs before cementation



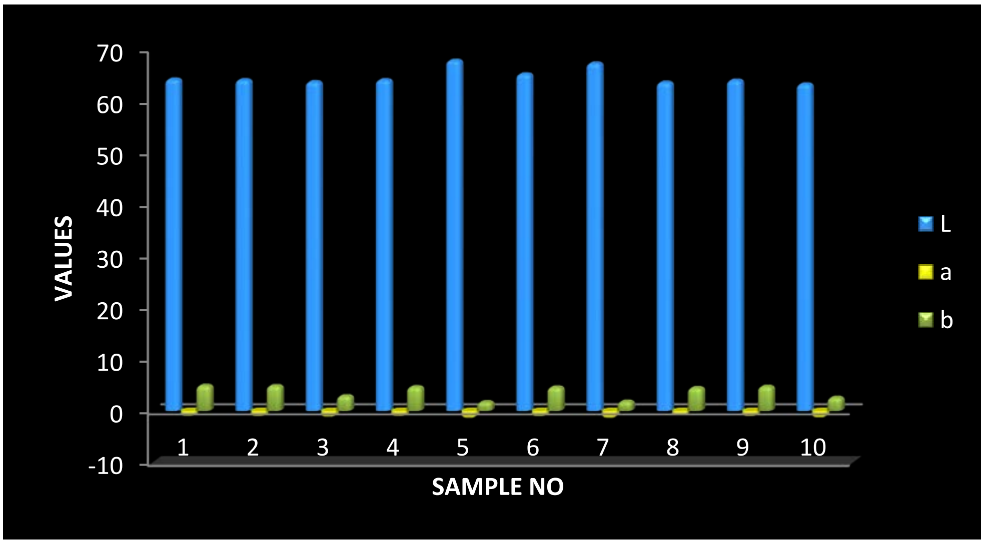
Graph 6: Basic data of L*a*b* values for Group III Lithium disilicate ceramic discs of thickness 1.6mm against Ni-Cr metal discs before cementation



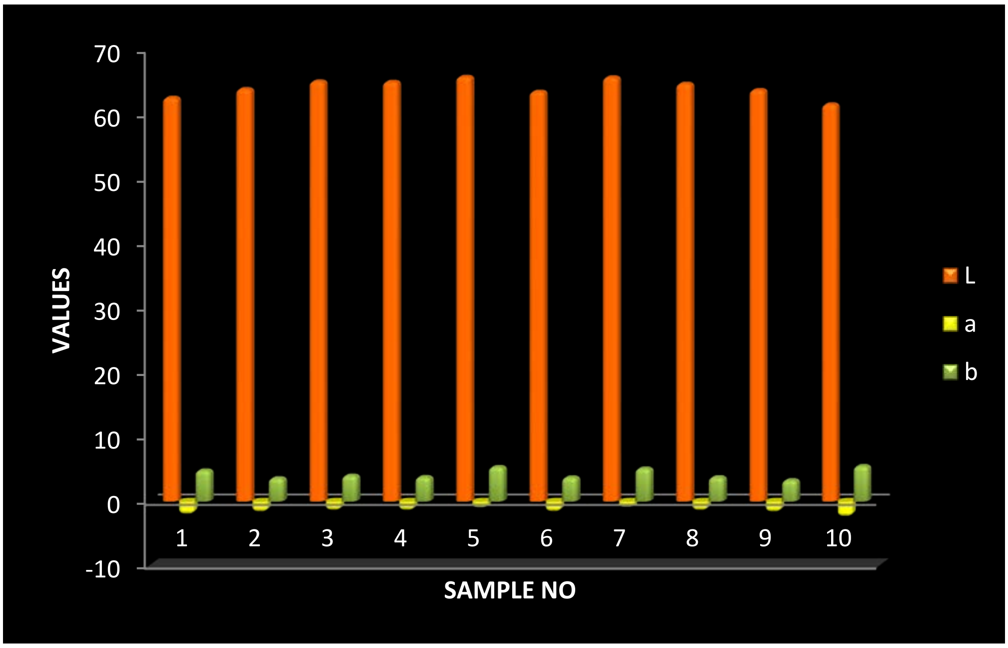
Graph 7: Basic data of L*a*b* values for Group I Lithium disilicate ceramic discs of thickness 1 mm after cementation with Ni-Cr metal discs



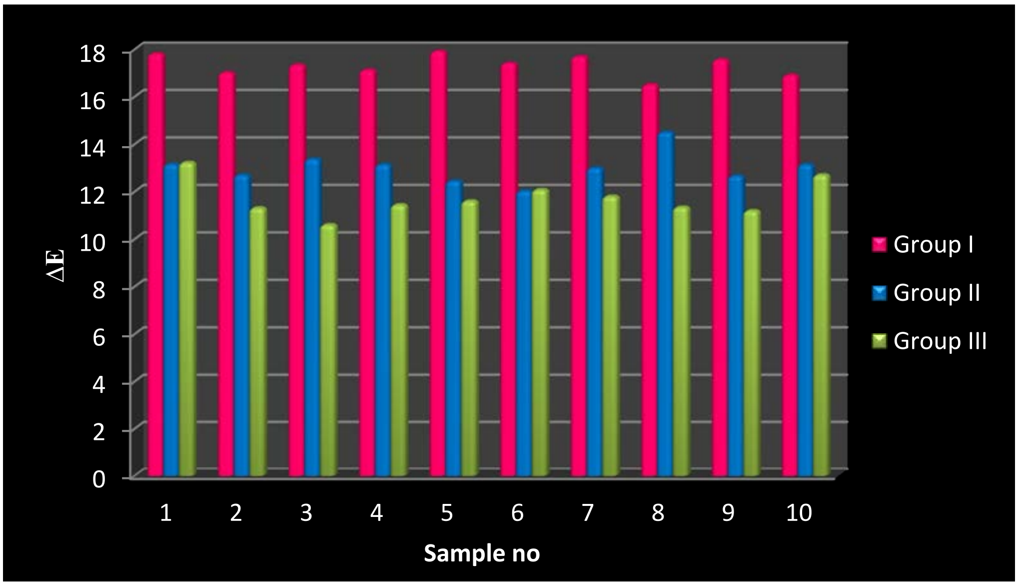
Graph 8: Basic data of L*a*b* values for Group II Lithium disilicate ceramic discs of thickness 1.3 mm after cementation with Ni-Cr metal discs



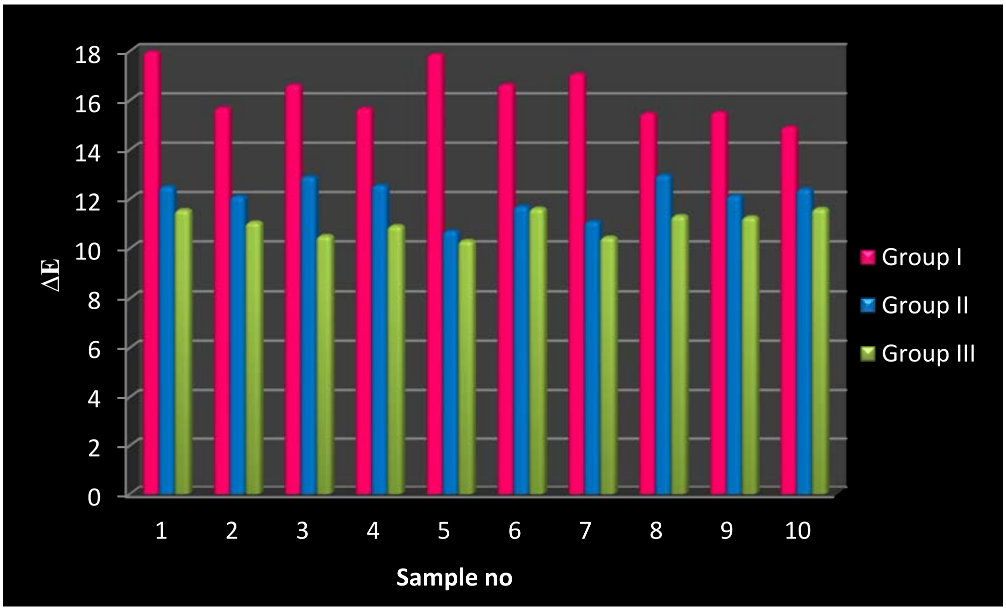
Graph 9: Basic data of L*a*b* values for Group III Lithium disilicate ceramic discs of thickness 1.6 mm after cementation with Ni-Cr metal discs



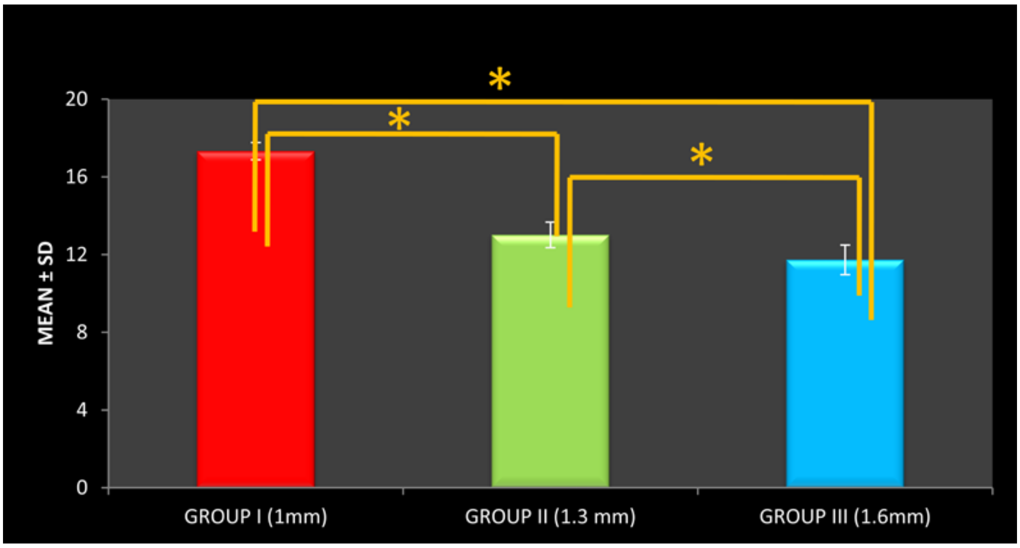
Graph 10:Comparative evaluation of colour difference (ΔE) between Group I (1mm), Group II (1.3mm) and Group III (1.6 mm) ceramic discs against white background and Ni-Cr metal discs before cementation



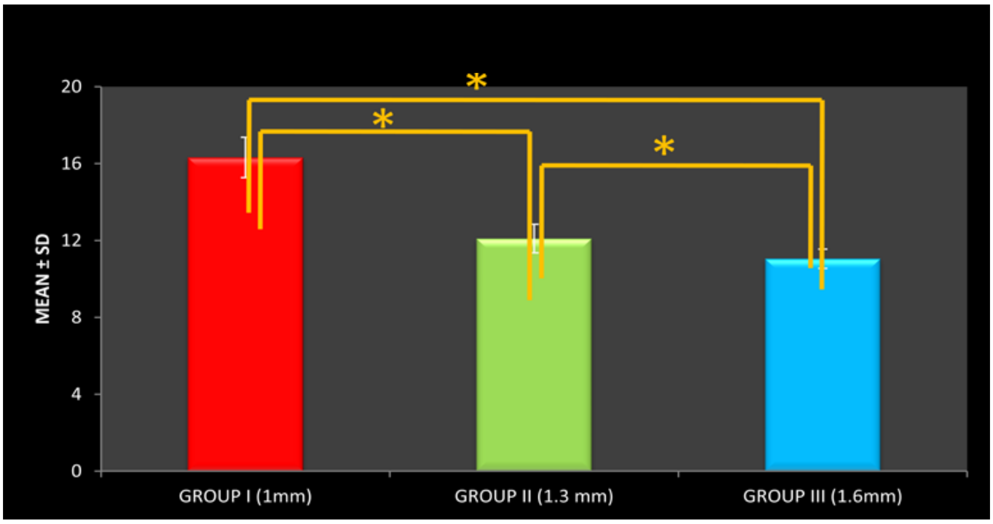
Graph 11 Comparative evaluation of colour difference (ΔE) between Group I (1mm), Group II (1.3mm) and Group III (1.6 mm) ceramic discs against white background and Ni-Cr metal discs after cementation



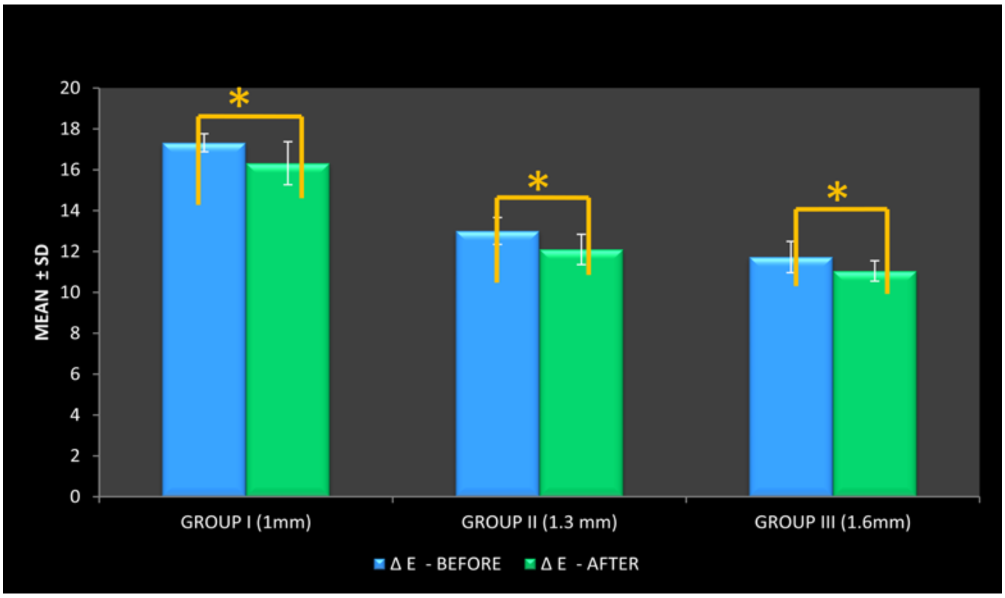
Graph 12: Overall comparison of the mean colour difference (ΔE) between Group I (1mm), Group II (1.3mm) and Group III (1.6 mm) ceramic discs before cementation



Graph 13: Overall Comparison of the mean colour difference (ΔE) between Group I (1mm), Group II (1.3mm) and Group III (1.6 mm) ceramic discs after cementation



Graph 14: Comparison of the mean colour difference (ΔE) of before and after cementation for Group I (1mm), Group II (1.3mm) and Group III (1.6 mm)



Discussion

DISCUSSION

The present *in vitro* study was conducted to comparatively evaluate the masking ability of lithium disilicate ceramic with different core thickness on the shade match of indirect restorations over metallic substrate.

The successful outcome of fixed dental prosthesis especially in the anterior aesthetic zone relies mainly on the biomaterials selected and the astuteness of the Dentist/laboratory technician.[26] The dynamic environment of the oral cavity presents a challenging situation in obtaining a predictable shade match and also the materials employed in the fabrication should meet certain prerequisites such as superior optical properties and minimal wear, essential for a durable service .[57, 70]

The intense quests among the dental professionals towards dentofacial esthetics have paved way for greater utilization of anterior aesthetic restorative materials mainly the all-ceramic systems. All-ceramic based materials possess excellent optical properties such as opalescence, translucence and resistance to wear and also exhibit excellent marginal adaptation.[3,54] The aesthetic limitation imposed by Porcelain Fused to metal restorations has led to the usage of metal free restorations mainly Lithium disilicate ceramic and zirconia in recent years.[26,55,64]

Various aspects of Lithium disilicate ceramic such as its optical properties, its composition and surface luster have been investigated in vitro in an effort to simulate the life like appearance of a natural tooth .Studies conducted by Harada et al on the colour matching abilities have proven superior optical behaviour of Lithium disilicate ceramic and this has prompted its use in the fabrication of aesthetic crowns, veneers and onlays in fixed prosthodontics .[34]

IPS emax press Lithium disilicate ceramic with flexural strength of 360-400 MPa has been used widely as a core ceramic upon which veneering ceramic is layered.[10,24,25,68] The overall optical behaviour of all-ceramic restoration is dependent on three factors: a) underlying abutment substrate b) resin luting agent c) the structure of ceramic material.[1,2,4,43] A chief concern towards the use of Lithium disilicate ceramic in the anterior visible zone for masking discoloured substrates is the shade mismatch especially in situations where the substrates are metallic cast post and titanium implant abutment.[53,56,69,71] To overcome this problem, blanks of different translucencies are used.[53]

Recent research involving Lithium disilicate ceramic in esthetic dentistry is largely focussed on these parameters .Studies done on the masking ability of Lithium disilicate against metallic substrates are relatively few and has been done only in recent years .A study conducted by Shao et al compared the masking ability of lithium disilicate of 0.8mm thickness and different cores of zirconia at 0.5mm and the results showed that lithium disilicate discs produced greater ΔE which can be discerned by the human eye, resulting in an unesthetic restoration.[58] Harada et al made a comparative evaluation of the translucency of different types of zirconia and lithium disilicate for monolithic restorations at thickness 0.5mm and 1mm and concluded that emax CAD LT was more translucent than all zirconias.[34]

These studies were performed to evaluate the masking potential of Lithium disilicate ceramic system of different translucencies and to provide clinical recommendation pertaining to the core thickness and method of fabrication to be employed. However, the outcomes of these studies are in discord.

The shade mismatch of the final restoration often leads to the remake as it is deemed unesthetic by the dentist /patient .Although conventional shade tabs is a routine modality in the shade selection process the use of spectrophotometer has been thoroughly researched and is now considered a standard approach.[22,44] CIE Lab system is a commonly used spectrophotometric analysis to evaluate the colour coordinates, the translucency parameter and has been widely used in several invitro studies to evaluate the masking ability of all-ceramic systems against different substrate.[29,38]

Studies evaluating the masking ability of various ceramics such as Leucite, alumina and Zirconia are well established.[13,43] Studies utilising heat Press ceramics are found to be limited. It is a well proven fact that optical properties are an ideal prerequisites for the aesthetic success of an indirect restorations.

In view of the above discussion, the present *in vitro* study was aimed to comparatively evaluate the masking ability of lithium disilicate ceramic with different core thickness on the shade match of indirect restorations over metallic substrate.

In the present study, Lithium disilicate ceramic discs of varied thickness were used to simulate the core portion of an all-ceramic restoration. A total of 30 test disc samples were prepared and was designated as Group I, Group II and Group III each containing 10 test samples respectively .Group I test samples comprised of Lithium disilicate ceramic disc of 1mm thickness, Group II test samples comprised of Lithium disilicate ceramic disc of 1.3 mm thickness and Group III test samples comprised of Lithium disilicate ceramic disc of 1.6 mm thickness. Thirty Ni-Cr alloy discs were also employed to represent metal substrate and were further randomly divided into 10 metal discs for each thickness of lithium disilicate ceramic disc to be used during CIE Lab analysis.

Spectrophotometer was used to measure the L*a*b* values of the test samples over white and black backings and the colour difference (ΔE) is then calculated from the L*a*b* values .In this study , a standard white A4 sheet was used as white backing and Ni-Cr metal disc to simulate the black background. Distilled water was used between Lithium disilicate ceramic disc and Ni-Cr alloy disc during the pre-cementation colour analysis .[6, 23] This is to ensure, that light scattering between the interfaces are minimal .A similar protocol was followed in a study done by Basso et al. [6] All the test samples were subjected to CIE Lab analysis before and after cementation and the values were computed and tabulated.

The results of the present study revealed that the L* values of lithium disilicate ceramic against white background decreased as the thickness increased (Table 1-3) .The reduction in L* value is based on the phenomenon that more light is absorbed with the thicker specimens and less light is reflected resulting in decrease in the brightness. These results are in agreement with the results obtained from the study conducted by Shono et al.[60]

The influence of Ni-Cr metal disc on the lithium disilicate ceramic when analysed over white background, before and after cementation exhibited a decrease in L*a*b* values in all the three groups(Table 4-9). However, on increasing the thickness of lithium disilicate ceramic, the effect of Ni-Cr metal disc produced an increase in L* and b* values and a reduction in a* values which is substantiated in a study done by Shimada et al .[59]

The results of the present study exhibited mean colour difference (ΔE) of Group I before and after cementation with the Ni-Cr metal discs was found to be 17.32 and 16.32 respectively (Table 10 & Table 11).

The mean colour difference (ΔE) of Group II before and after cementation with the Ni-Cr metal discs was found to be 13.01 and 12.10 respectively (Table 10 & Table 11).

The mean colour difference (ΔE) of Group III before and after cementation with the Ni-Cr metal discs was found to be 11.73 and 11.05 respectively (Table 10 & Table 11).

The ability of the human eye to notice differences in colour varies among individuals, different ΔE intervals are used to distinguish differences in colour: ΔE values < 1 are considered undetectable by the human eye. The literature provides different values of colour difference for the perceptible and acceptable thresholds when examined *in vitro / in vivo* conditions. The perceptible threshold ΔE in different investigations ranges from 1.0 to 3.7 and the acceptable ΔE threshold ranges from 1.7 to 6.8. In this study, the $\Delta E > 3.3$ suggests perceptible colour change. If a ΔE value is greater than 5.5 it is regarded as a clinically unacceptable colour change. [12, 72]

The increase in colour difference (ΔE) of lithium disilicate disc under the influence of Ni-Cr metal discs , is due to reduction in L*a*b* values .As the thickness of the ceramic discs increased there seemed to be reduction in ΔE and this can be correlated to the increase in L* and b* values and reduced a* values. This increase in thickness resulting in lower ΔE values is in agreement with study done by Vichi et al.[69] In this present study, the Ni-Cr metal alloy used as metal substrates yielded higher ΔE values which is suggestive of major difference in colour when compared to the perceptible threshold, whereas studies done using noble metal alloy substrates containing gold produced ΔE values closer to the perceptible range and this is attributed to the yellowish hue of the noble metal alloys used .[19,48]

Studies have also suggested the thickness for an all-ceramic restoration for a standard vital tooth preparation should be 2.0 mm [68,69] to reproduce the normal contour and optical properties , but achieving such axial reduction for aesthetic reasons in discoloured abutments can be deleterious to the pulpal health and can also result in a less retentive or unesthetic over contoured restoration.[48] To achieve ideal aesthetic outcomes, restorative materials should have proper opacity that can mask the underlying substrate colour and offer optimum translucency to represent that of the natural teeth.[49] Analysis of colour difference using different core thicknesses have been evaluated in earlier studies, Zhou et al conducted a study using high opaque series of lithium disilicate ceramic for masking Ni-Cr metal abutments and suggested use of 0.6mm, 0.8mm thick High Opaque lithium disilicate ceramic for better masking of discoloured substrates .[74] In addition, increasing the opacity of the ceramic core adversely affects the aesthetic properties of the restoration. Thus a low-translucency material is able to mask underlying dark backgrounds but might not create natural tooth characteristics. Therefore, using a multilayer ceramic restoration including an opaque core for masking the underlying discoloured substrate and veneering ceramic is recommended to achieve predictable aesthetic results.[21, 61]

White opaque cement has demonstrated better masking ability than cements of other shades.[12, 20,52] White opaque cement yielded acceptable shade match when tested at 50µm and 100µm film thickness against Ag-Pd metal substrate as studied by Niu et al .[48] In the present study , thickness of the resin luting cement was standardized at 40µm which is well within the film thickness range for resin luting agent (25-40 µm). On analysing the influence of white opaque cement on the colour difference of lithium disilicate against Ni-Cr metal disc, decrease in ΔE was observed in all the three groups which is due to the increased L* and b* values with decrease in a* values and this is in accordance to study made by Niu et al.[48] Thus, in the present study, the White opaque resin cement did not show marked decrease in the ΔE value after cementation.

On statistical comparison of the mean colour difference (ΔE) before cementation and after cementation revealed statistically significant difference ($p<0.05$) among the three groups (Table 12 to Table 15). On statistical comparison of mean colour difference before and after cementation within the three groups revealed that Group I, Group II and Group III are statistically significant ($p<0.05$) (Table 16). Group III had the least mean colour difference, followed by Group II with a relatively higher mean colour difference and Group I with the highest mean colour difference (Group III <Group II < Group I) indicative of better masking ability of Group III compared to Group I and Group II before and after cementation.

Lithium disilicate exhibits good translucency because of the refractive index of crystal is close to that of glass matrix resulting in less scattering.[1,38,59,71] The low translucent blank used in this present study contains increased number of nanocrystals of lithium phosphate and lithium zinc silicate resulting in improved opacity of the blank, providing acceptable masking ability with exceptional aesthetics .[61] However in the present study ,the masking ability of lithium disilicate ceramic on Ni-Cr metal substrate did not yield $\Delta E < 3.3$ for all the three groups .This increase in ΔE is because of the optical characteristic of the material .

It must be noted that, when the underlying abutment tooth discolouration is too intense, the option of using heat pressed Low-translucency (LT) lithium disilicate ceramic blank may be limited. Ceramic blanks of medium opacity (MO) or high opacity (HO) that are designated for fabrication of core structures might be suitable for this situation. Since the opaque colour core structure is of high opacity, it is suggested that the core structure be veneered with veneering ceramic to enhance aesthetic results.

The present study had some limitations, for better understanding of the optical properties, translucency parameter and contrast ratio could have been analysed to yield more predictable results. Newer metal free core materials such as PEEK and Nanozirconia with different levels of opacity should be evaluated for their masking ability.

The present study provided additional scientific support to overcome the clinical challenge of aesthetically masking dark substrates, such as metal foundation, using all-ceramic restorations. Yet there still is a need for further investigation on whether increasing the thickness of the framework as well as the use of opaque cements and/or opaque pigments could offer acceptable masking of metal substrates.

Conclusion

CONCLUSION

The following conclusions were drawn based on the results obtained in the present *in vitro* study evaluating the masking ability of Lithium disilicate ceramic with different core thickness on the shade match of indirect restorations over metallic substrate:

1. The mean L*a* b*values of Group I Lithium disilicate ceramic discs (1mm) against white background were found to be **76.95, -0.48** and **9.4** respectively (Table 1).
2. The mean L*a* b* values of Group II Lithium disilicate ceramic discs (1.3mm) against white background were found to be **74.48, 0.003** and **10.85** respectively (Table 2).
3. The mean L*a* b* values of Group III Lithium disilicate ceramic discs (1.6mm) against white background were found to be **72.44, 0.017** and **11.50** respectively (Table 3).
4. The mean L*a*b* values of Group I Lithium disilicate ceramic discs (1mm) against Ni-Cr metal discs before cementation were found to be **61.26, - 1.26** and **2.07** respectively (Table 4).
5. The mean L*a*b* values of Group II Lithium disilicate ceramic discs (1.3mm) against Ni-Cr metal discs before cementation were found to be **63.80, -1.19** and **3.40** respectively (Table 5).
6. 6) The mean L*a*b* values of Group III Lithium disilicate ceramic discs (1.6mm) against Ni-Cr metal discs before cementation were found to be **63.79, -1.46** and **3.68** respectively(Table 6).

7. The mean L*a*b* values of Group I Lithium disilicate ceramic discs (1mm) after cementation with Ni-Cr metal discs were found to be **62.27, -1.29** and **2.35** respectively (Table 7).
8. The mean L*a*b* values of Group II Lithium disilicate ceramic discs (1.3mm) after cementation with Ni-Cr metal discs were found to be **64.72, -1.38** and **3.77** respectively (Table 8).
9. The mean L*a*b* values of Group III Lithium disilicate ceramic discs (1.6mm) after cementation with Ni-Cr metal discs were **64.16, -1.68** and **4.37** respectively (Table 9).
10. The mean colour difference (ΔE) of Group I, Group II and Group III Lithium disilicate ceramic discs against white background and Ni-Cr metal discs before cementation were found to be **17.32, 13.01** and **11.73** respectively (Table 10).
11. The mean colour difference (ΔE) of Group I, Group II and Group III Lithium disilicate ceramic discs against white background and Ni-Cr metal discs after cementation were found to be **16.32, 12.10** and **11.05** respectively (Table 11).
12. On comparison, all the three groups revealed statistically significant differences between their respective mean colour difference (ΔE) before cementation ($p<0.05$), with Group III (**11.73**) having the least mean colour difference, followed by Group II with a relatively higher mean colour difference (**13.01**) and Group I with the highest mean colour difference (**17.32**) ($p<0.05$) (Table 12 and Table 13).

13. On comparison, all the three groups revealed statistically significant differences between their respective mean colour difference (ΔE) after cementation ($p<0.05$), with Group III (**11.05)** having the least mean colour difference, followed by Group II with a relatively higher mean colour difference (**12.10)** and Group I with the highest mean colour difference (**16.32)** ($p<0.05$) (Table 14 and Table 15).

14. On comparative evaluation, of the mean colour difference (ΔE) before and after cementation of all the three groups showed lesser ΔE values after cementation than before cementation. The mean colour difference of Group III showed the least ΔE value after cementation among all the test groups indicative of better masking ability of Group III compared to Group I and Group II (Table16).

Summary

SUMMARY

The present *in vitro* study was conducted to comparatively evaluate the masking ability of lithium disilicate ceramic with different core thickness on the shade match of indirect restorations over metallic substrate.

Ten heat pressed lithium disilicate ceramic discs of low translucency were fabricated with diameter 10mm and thickness of 1 mm, 1.3mm and 1.6mm each, making a total of 30 ceramic disc specimens. Thirty metal disks of diameter 10mm were cast from Ni-Cr alloy pellets to serve as metal substrate. The $L^*a^*b^*$ parameters were measured according to CIE using D65 Illuminant and observer function at 10° with CM-3600d spectrophotometer in wavelength 360-740 nm. The L*a*b* of the ceramic discs against white background and against Ni-Cr metal discs without cementation were measured. To analyze the masking ability of lithium disilicate ceramic disc, the specimens were surface treated with 10% hydrofluoric on the side to be cemented with Ni-Cr metal disc. The cement thickness was maintained at 40µm. To ensure complete polymerization, the cemented specimens were placed in distilled water for 24 hrs and later analyzed for its colour co-ordinates. The colour difference before and after cementation were calculated. The data was statistically analyzed using One –way ANOVA and paired t-test.

The mean ΔE values of Group I, II and III before and after cementation was 17.31, 13.01, 11.73 and 16.32, 12.10, 11.05 respectively.

In the present study, the perceptibility threshold of $\Delta E < 3.3$ was set as clinically acceptable threshold but from the results obtained, it was evident that all the 3 groups showed higher ΔE values when compared to the perceptibility level. Group III (1.6 mm)ceramic discs resulted in lower ΔE value when compared to Group II(1.3mm) & Group I (1 mm) suggestive of better masking ability of Group III ceramic discs and this implies that increase in thickness of the ceramic core results in increased masking ability. Thus, the null hypothesis of this study was refuted.

The different thicknesses of Low translucent lithium disilicate ceramic used in this study were not able to mask the colour of the metal substrate efficiently. Hence, the indication of Low translucent lithium disilicate ceramic should be used judiciously. Thus, in clinical situations when metallic foundations are encountered, increase in thickness of the ceramic, selection of opaque core and use of opaque luting agent would result in a predictable esthetic restoration.

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ANNEXURE IV

URKUND

Urkund Analysis Result

Analysed Document:	PLA I DISSERTAION.docx (D35155023)
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